A Semi-Monthly Technical Newspaper

Metallurgical & Chemical Engineering

New York, September 1, 1916 McGraw Publishing Co., Inc. Vol. XV, No. 5 25c a copy

Metallurgical and Chemical Engineering

A Consolidation of
ELECTROCHEMICAL AND METALLURGICAL INDUSTRY and IRON AND STEEL MAGAZINE

Vol. XV — NEW YORK, SEPTEMBER 1, 1916 — No. 5

PUBLISHED SEMI-MONTHLY ON THE FIRST AND FIFTEENTH OF EACH MONTH BY THE

McGRAW PUBLISHING COMPANY, INC.

JAMES H. McGRAW, President.
A. E. CLIFFORD, Secretary. JOHN T. DEMOTT, Treasurer
239 West 39th St., New York.

TELEPHONE, 4700 BRYANT. CABLE ADDRESS, METCHAM, NEW YORK.
ROCKY MOUNTAIN OFFICE.........421 Boston Bldg., Denver, Col.
PACIFIC COAST OFFICE......502 Rialto Bldg., San Francisco, Cal.
CHICAGO OFFICE..........................Old Colony Building
CLEVELAND OFFICE.........................Leader News Building
PHILADELPHIA OFFICE................Real Estate Trust Building
LONDON OFFICE..............Hastings House, Norfolk St., Strand

E. F. ROEBER, PH.D., Editor.
H. C. PARMELEE, Western Editor.

J. MALCOLM MUIR, Manager.

Yearly subscription price for United States, Mexico and United States dependencies, $3.00; all other countries, $4.00.

Entered as Second-Class Matter at the Post Office at New York, N. Y., under the Act of Congress, March 3, 1879.

Contents for September 1, 1916

EDITORIAL:
Two Coming Technical Society Events.......... 221
The Iron Industry after the War.......... 221
Tied Hands.......... 222
The By-Product Coke Oven.......... 222
The Commissioner of Chemistry.......... 223
READERS' VIEWS AND COMMENTS:
Electrometallurgy of Iron and Steel and Pacific Coast Waterpowers. By J. O. Boving.......... 224
Red-Hot Summer-Day Inventions. By Peter ten Broeck. 224
Coming Meetings and Events.......... 225
Edinburgh Meeting of Society of Chemical Industry.......... 225
The Iron and Steel Market.......... 226
The Non-Ferrous Metal Market.......... 227
Notes on Chemical and Metallurgical Engineering in Great Britain.......... 227
Second National Exposition of Chemical Industries.......... 229
Program of New York Meeting of American Chemical Society 229
New York Meeting of American Electrochemical Society...... 230
Program of Ladies Committee of American Chemical Society and American Electrochemical Society.......... 230
Cleveland Meeting of American Institute of Metals.......... 230
Rubber Vulcanization Accelerators. By Andrew H. King.... 231
Commercial Considerations Concerning the Blast Furnace. By J. E. Johnson, Jr.......... 235
Annealing of Aluminum. By Richard Seligman and Percy Williams.......... 244
The Time Factor in the Formation of Aromatic Hydrocarbons from a Paraffin Base Oil. By Gustav Egloff and Thomas J. Twomey.......... 245
Maximum Watt Dissipation in Still Air from Nickel Wire. By E. F. Northrup.......... 250
Notes on Copper Smelting at the United Verde Copper Company.......... 251
Some Technical Applications of Capillary and Electrocapillary Chemistry. By W. C. McC. Lewis.......... 253
The Active Materials and Electrolyte of the Alkaline Storage Battery. By L. C. Turnock.......... 259
SYNOPSIS OF RECENT CHEMICAL AND METALLURGICAL LITERATURE.......... 262
RECENT CHEMICAL AND METALLURGICAL PATENTS.......... 264
Measuring Water with a Weir Meter. By E. G. Bailey...... 267
New Design of Automatically Controlled Low-Pressure Valve. 268
Enlarging Photographs Without the Use of a Lens.......... 269
PERSONAL.......... 270
INDUSTRIAL NOTES.......... 270
DIGEST OF ELECTROCHEMICAL U. S. PATENTS.......... 271

Two Coming Technical Society Events

The last two weeks of September will bring two technical society events of nation-wide importance. During the week of September 18 the American Institute of Mining Engineers will meet in Arizona, now easily the leading copper-producing State. This will be the first Arizona meeting in the Institute's history of forty-five years. Sessions will be held in the principal mining centers of the State, the members traveling between the various points by special trains and automobiles. An excellent technical program has been arranged, including an important discussion on concentration and flotation. The principal sessions will be held at Santa Rita and Hurley, N. M., and at Douglas, Bisbee, Globe and Phoenix, Ariz. The inspections will include the Roosevelt Dam, the mines and works of the Chino Copper Co., the Copper Queen Consolidated Mining Co., Calumet & Arizona Copper Co., Shattuck Copper Co., Inspiration Consolidated Copper Co., Miami Copper Co., Old Dominion Copper Mining & Smelting Co., together with the new works of the International Smelting Co. There can be no doubt that the Arizona meeting will be as enjoyable and successful as the unforgetable Montana, Utah and California meetings of the past three years.

The week of September 25 will be Chemical Week in New York City. The Second National Exposition of Chemical Industries will be held at the Grand Central Palace, and it is now assured that it will be even bigger and more representative than the immensely successful First Exposition of last year. In conjunction with the exposition the two largest national chemical societies of this country—the American Chemical Society and the American Electrochemical Society—will hold meetings in New York City, and unusual efforts are being made to render these events as enjoyable and profitable as possible.

The only pity is that the Arizona meeting of the Mining Engineers and the chemical exposition and conventions come so near together as to make it practically impossible for any one to attend both events. Yet mining engineers and chemists would do well to try and get a little bit better acquainted.

Steel Capacity After the War

The American iron and steel industry never shows a perfect alignment as to capacity in the different departments. All departments strive for maximum output when the market will absorb the product and every period of activity witnesses wholesale breaking of records whereby balances between departments are disturbed. Then there are fluctuations in the alignment of demand, the consumption of some finished steel

products increasing more rapidly than that of others. In 1903 the production of structural shapes was 27 per cent less than the production of wire rods; in 1913 the production was 22 per cent greater. Until 1904 the production of rails exceeded that of plates and sheets; in 1913 plates and sheets exceeded rails by 64 per cent.

The war has furnished the greatest disturbance of all, and the alignment of capacities in the different departments at the close of the war will doubtless be found quite unsuited to the conditions of a peace demand. There has been a remarkable increase in the production of ingots, as compared with the production of pig iron on the one hand and of finished steel on the other. A part of the increase in ingot production is attributable to the unusually large supplies of heavy melting steel available, due to the heavy cropping involved in the manufacture of shell steel, and this excess will automatically disappear. Apart from this increase, however, there has been an increase in the steel-making capacity relative to finishing capacity, and this will not disappear. The excess is represented at present in the exportation of large tonnages of forging billets and other unfinished steel, together with large tonnages of rounds rolled on rail mills. The rail mills are very busy, although the domestic demand for rails has been relatively light.

The most striking lack of harmony disclosed by the actual market prices prevailing is the shortage of steel-making capacity relative to pig-iron producing and steel-finishing capacity, whereby there is an unprecedentedly large gap between pig-iron prices and unfinished steel prices. Basic pig iron has been selling at an average price of $19 to $20, delivered at steel works, while billets, slabs and sheet bars are quoted nominal at $45 to $50, being almost unobtainable at any figure. Light gage sheets and wire nails are selling at considerably less than the bare cost of conversion above the current market prices for their raw materials. The market price of unfinished steel is not made by demand for sheet bars, or perhaps, even for billets, in the domestic market, but is caused by high bids for slabs from domestic plate mills, and by heavy export demand for nearly all descriptions of unfinished steel. After the war the alignment will necessarily be quite different. Pig iron and unfinished steel will not be so widely separated. Plates will not sell at $8 a ton more than structural shapes.

Tied Hands

We are just as patriotic as the next fellow; we hold the fair name and fame of our beloved land as a sacred thing and we do not believe in carping criticism. But sometimes we get a little confused. We stand by the Constitution, but we do not always know just which way to look while we are standing there. For instance, here is a letter from the Director of the United States Geological Survey to one of the managers of the Chemical Exposition, which we print with permission: "I regret with you that there is practically no possibility of Congress passing a bill appropriating funds to allow the Government Bureaus participating in the Second National Exposition of Chemical Industries. In view of Congress' apparent desire to prevent the various bureaus taking part in this project as well as its former order against allowing employees to be detailed to scientific meetings, etc., at the expense of the Government, I am constrained to inform you that it will not be possible for the Survey to send an exhibit to New York for the exposition and it will therefore be unnecessary to hold space for our use. I trust that several of the chemists and geologists will be able to visit the exposition on leave at their own expense, and I hope that you will meet with the same success that attended the first exhibit of this sort."

It is all right for Congress to hold a tight rein upon the Government, but does it take a special bill to send up a little exhibit? The work of the Government for the people needs to be brought to their attention so that they may know what it is doing—at least, so it would appear—and yet Congress, so lavish with post-office buildings for small towns and special pensions that have been refused by the pension authorities and the dredging of small creeks for the "extension of commerce," seems to think otherwise.

That will be quite an exhibit in the last week in September, and if present signs do not fail, it will be very largely attended. The Geological Survey works for all the people. It costs far less than pensions and it is more useful and more interesting. It knows a great deal about the mineral deposits of the country and industry would like very much to be posted. This would extend commerce far more than many of the duck ponds for which Congress has made such generous appropriations. Maybe Director Smith draws too fine a line in regard to the authority vested in him, and yet if he can't exhibit, we don't see how he can. It is confusing; very confusing. Especially as the Bureau of Mines is sending a very considerable exhibit.

The Byproduct Coke Oven

In our issue of July 15 (page 56) we commented on the marvelous rate at which the iron industry of this country is now adopting the by-product coking process. But as a remark at the end of that note concerning the by-products recovered has been misunderstood, it may not be amiss to restate the situation exactly. The facts are that there are practically no by-product coke plants in the United States, which do not recover ammonia, tar and light oil (crude benzols). In the vast majority of the plants also surplus gas is recovered and utilized either at the plant itself or by distribution to outside consumers. There are possibly two or three very small by-product coke plants at which tar and ammonia are not recovered for disposal to the outside markets, but these would certainly represent considerably less than 1 per cent of the total by-product coking capacity. There is not over 5 per cent of the by-product coke oven capacity of the country that is not now equipped with benzol recovery plants, and the by-product coking plants now under construction have either contracted for benzol recovery equipment or indicated a strong probability that such provision will be made.

This development is industrially important and interesting in more than one direction. We may consider the utilization of the by-products recovered and rejoice of the foundation of new industries in this country. This is perhaps the most natural way to look at the by-product coke oven development. But we may also consider the effect which this development has had on the iron industry. One of the most interesting technical effects is brought out very clearly in the article by Mr. J. E. Johnson, Jr., on commercial considerations concerning the blast furnace, published in this issue. A few years ago maximum degree of fuel economy was not only technically desirable, but was commercially necessary for survival, but this is no longer the case. There are conditions in which the commercial results are better with very moderate fuel economy than with the highest. The two developments which have brought about this change are the introduction of the by-product coke oven and the economic development of power generation with blast furnace gas, especially the gas engine. Mr. Johnson's very lucid demonstration of this peculiar situation should be read with decided interest.

The Commissioner of Chemistry

There is a man in Jamaica, Long Island, who has a boy named Donald, twelve years old. He left home for a visit to Mount Beacon, N. Y., and he returned a week later. "When Donald went away," said his father to a New York **World** reporter, "he was four feet ten inches in height and weighed seventy-two pounds. When he got back to-day his mother was so amazed at his appearance that we measured him again and found that he was five feet two and three-quarters inches tall and weighed eighty-two pounds."

He had grown four and three-quarters inches in eight days.

Donald is like some chemical industries in this country in that both have made a record growth, but there the resemblance ends. Donald has a father and mother to look after him, to discourage cigarettes and wet feet and bad companions. It is not so with many of our blooming young chemical industries. They have no father and mother to look after them. What will they do on the day when they get cold feet?

Some time or other the big war will be over and ships will be sailing on the seas. The Japanese have entered into the chemical habit, and a lot of munition works in the Rhine country will shift back into making other chemical products. They can do it because the equipment is there. The reporter who thought that all the shell makers and TNT institutions and "Pickwick Acid" layouts in the United States could shift over into making alizarine and indigo and fast cotton colors and intermediates and all the wanted things, by a twist o' the wrist, was wrong; but over in Germany the equipment and the art to make the things they used to produce will be available. Chemical manufacture is growing in Norway and Sweden by leaps and bounds, and England has developed a chemical consciousness. The Scotch have taken to chemistry, and that means trouble—outside of Scotland. In all of the countries mentioned there is great encouragement for manufacturers to get together and co-ordinate their work. Every country is resolved to be self-contained or burst a lung in the attempt, and every country is also firmly resolved to cultivate and prosecute an active export trade. Now, nobody outside of Congress believes that in American chemical industry there is good, co-ordinated system. And the time is coming when these efforts at export trade will be made by sister nations on every hand. Then we can talk protection until we are blue in the face and insist upon it that the man who buys foreign goods is without patriotism and we can call him a traitor and all the hard names we can think of—but nothing will help except system and order and co-ordination.

So chemical industry needs a leader who is long on knowledge and experience in the markets as well as in industry; who can say disagreeable things and yet be cheerful about it, and who is not committed to any particular organization. He should be a successful man who has made his pile and who has a liking for bringing about results. The place for him would be in some department of the government at Washington, where information would come to him at first hand and where he could do some co-ordinating without breaking the law.

This sort of thing can only be done from the Heights of Government. We have the grave difficulty that only Government may do those things that business men may do in most other countries. Under the Sherman law, a tricky lawyer can construe nearly every manufacturer, no matter how consciencious and innocent of all evil he may be, into a criminal by a possible "theory of the case"; and American manufacturers have lost initiative under it. Some manufacturers' associations have dwindled down into weak imitations of a comedy hen-party in which the talk, restricted to the difficulties with household servants, is changed over into talk restricted to the guile and the wiles of labor unions. The iron and steel industry is in good shape because manufacturers learned the value of co-operation before the Sherman law broke out and they have the habit of keeping themselves posted. The chemical industry is not in this condition and manufacturers are not posted. And they dare not post themselves save under a standing threat from the Attorney General.

The Agricultural Department keeps farmers informed about the wheat crop, the cotton crop, foreign production and the markets. Why not do the same for chemical industry Everybody wants chemical industry to thrive, and it cannot thrive unless it knows what is being made and landed, where it is coming from, how much of various materials are being produced and something about the markets. It needs the same kind of paternal care that it gets in other countries just as much as it needs protection.

We have no idea where the Commissioner of Chemistry would fit in, but there is room for him and need of him—unless he is to be a politician, or, in fact, anyone other than a man worth far more than his salary.

Readers' Views and Comments

Electrometallurgy of Iron and Steel and Pacific Coast Waterpowers

To the Editor of Metallurgical & Chemical Engineering

SIR:—In your issue of July 1, in a very interesting article by J. W. Beckman dealing with electrochemical possibilities on the Pacific Coast as compared with those in Sweden and Norway, reference is made to the new electrothermal iron reduction which has been developed on a very large scale in Sweden, and as I am intimately acquainted with this situation I thought some information on the point might be interesting.

Mr. Beckman states that about 50,000 tons of iron are produced annually in the Swedish electric reduction furnaces. I may say that the output is now considerably over 100,000 tons, but it may be that Mr. Beckman's figures relate to a period about two years ago. Since then very large furnaces have been built which have a capacity of 10,000 hp. each, producing roughly 25,000 to 30,000 tons of pig iron annually. Compared with the ordinary blast furnaces, this capacity is, of course, only small, but it must be remembered that a very high-grade quality of pig iron is obtained, fetching good prices.

Most cf the electric-furnace installations are in the middle of Sweden, whereas the ore for several of them is transported from the far north, being hauled about 200 miles by railway, then 800 miles in ships, and then again a short rail journey at the other end. Charcoal is delivered to the iron works by the railways, and the collection area is enormously wide, so that it is not unusual for charcoal to be transported 300 miles. These facts are important when contemplating similar developments on the Pacific Coast. Mr. Beckman mentioned quite rightly that so far most of the charcoal is made direct in the forest in the old-fashioned way, but the tendency is now to concentrate in large plants, especially in connection with sawmills, where all the refuse is used for making charcoal. In such cases the plant is equipped with apparatus for distillation and preservation of by-products which, if properly done, yield so high a profit that the charcoal can be sold at a very low figure.

I venture to say that there is no place in the world where conditions are so exceptionally suitable for electric iron ore reduction as the Pacific Coast of the United States and Canada. If enterprising people went about this affair in a proper way, it should be extremely remunerative and help to develop industry generally. It would, of course, be advisable to make use of the reliable experience which has now been accumulated by Swedish engineers, and this is represented by a British firm, Electro-Metals, Ltd., of London, which controls all the American patents.

In Sweden, experiments have been carried out with many different types of furnaces, but only one type has proved to be a commercial success, and is now used at every plant throughout the country, viz., the reduction furnace belonging to Electro-Metals, Ltd.

The process has now been developed further in Sweden so that the molten pig is delivered direct to the open-hearth furnaces, heated by the gases from the reduction furnace, and, finally, the charge from the open-hearth furnace is poured into an electric refining furnace, and the final steel is of remarkably high quality. This is obviously the right method where electric current can be obtained at a reasonable price.

In this connection it will interest you to know that electric refining of steel has gained much ground during the war in this country (Great Britain). Some forty furnaces of varying capacity have been put in—most of them in the Sheffield district, but also in other parts of the country—and the success has everywhere been conspicuous. Not only is the quality of the steel such as could only be obtained previously in crucibles, but makers have found that in spite of the high price which they pay for current (approximately 1.5 cents per kilowatt-hour), there is no doubt that electric refining offers an extremely convenient and reliable method of dealing with impurities and determining a desired analysis of the steel. Any large electrothermic iron works on the Pacific Coast would be complete only with final electric refining as indicated above.

J. O. BOVING.

Boving & Co.,
London, W. C., England

Red-Hot Summer-Day Inventions

To the Editor of Metallurgical & Chemical Engineering

Sir—The man with a chemical past went to the Chemists' Club for luncheon. At a table in the Julep Garden sat three men at meat, a man of research, his assistant and a professor of physics. "Sit down at our table," said the man of research; "we are having an invention bee and we want you to help us. I am doing my bit for preparedness and my invention relates to ordnance, of course for purposes of defence."

"What is it?" asked the man with a chemical past.

"It is a gun," said the research man, "a four-foot gun. I mean four feet in diameter. You see, the trouble with the big guns of the present is that they are fired at an angle of thirty-five degrees and the projectile meets resistance from the air throughout its entire trajectory. With my bigger gun it will be possible to shoot at a much greater angle, and, given enough explosive force, when the projectile reaches a distance of eight miles above the earth, the air friction will become negligible, so the distance may be increased in proportion to the charge. Of course, to resist a force of such violence an extraordinary density of material will be required, and I have concluded that this may be obtained at very low temperatures. To meet this I propose the use of liquid air, and for a metal I have chosen mercury."

"Details to be worked out, I suppose," suggested the professor of physics.

"Certainly," answered the man of research. "I claim for my invention sufficient tensile strength to meet the requirements. I am only worried by two features: one is how to rifle the bore and the other is the nature of the projectile."

"Why don't you use a squirrel-cage device to twist your projectile around licketty-split before you fire her off?" asked the professor of physics.

"My hearty thanks, dear colleague," answered the man of research. "Your suggestion is gratefully accepted. It is merely a problem in engineering. We may count that feature as settled. Then, you observe, having shot off a few projectiles, it may be desirable to let fly at the enemy from another point. The thing to do is to surprise him. So I plan to run the mercury by pipe line to the next best place, set up the big gun again by means of liquid air, adjust the squirrel-cage device to give the proper twist, and annihilate the re-

serves. Everything is ready to work out except the projectile; I don't know what to fill it with."

"May I come in on this?" asked the man with a chemical past.

"Why not?" replied the research man. "This is welfare work, and every suggestion is acceptable."

"Well, I've been seeking immortality for over fifty years and haven't found it yet. Here is my chance. Fill 'em with mercaptan."

"Good!" exclaimed the research man. "I accept your proposal and shall fill the projectiles as you say. Now, I think we have the whole problem of preparedness settled, with my gun, your squirrel-cage twister and your mercaptan projectile."

"I feel that there is something more important than preparedness," said the professor of physics. "I want to meet public opinion. Preparedness is only a feature of public opinion. What is universally in the public mind is the desire for a Place in the Sun. That is something that everybody and every nation wants. My invention will endeavor to meet this desire. It recognizes the great water power of the United States, only a small fraction of which is used. I propose to harness all the waterfalls, develop every one of them, and have available to be connected with each one to the full capacity of its power, a great gyroscope, or series of them. These shall all be connected with a central control station. You may go ahead with your preparedness and have as many soldiers and guns as you please, but some nation is always sure to have more of them than we have. Remember that we always have Congress at Washington, and while Congress may be active and enduring in speech, it has never yet been intelligent. At least it has not in this generation. So I plan to have these gyroscopes connected up with the State Department in Washington. Then let us suppose that we have a point at issue with some European capital. An ultimatum is given to us to do as the authorities at the foreign capital require within twenty-four or forty-eight hours, or suffer the consequences. They proceed to mobilize, and still we are indisposed to do as we are told. It is possible for nations to feel that way. Very well, as the time set in the ultimatum draws to a close and we have not obeyed, the wise man who will then be in the State Department turns a little lever, the gyroscopes all begin to turn, the mathematically computed push is given in just the proper direction, the gyroscopes push the other way, harder and harder, exactly as planned, and straightway the earth proceeds to revolve on a new axis, and London or Berlin or any other capital that gets too gay—becomes the North Pole! As soon as the ultimatum is withdrawn, another little turn of the lever brings every country back to its accustomed climate again. In time, of course, the whole world would join in the gyroscopic control of the axis of the earth, and the North Pole dip would be used for the punishment of recalcitrant nations that want to go to war when they shouldn't. It would be a great convenience, also. For instance, after the harvests are over the people of Ontario and the Middle Western States want ice for their season's store. So they send in a petition, the Great Lakes are put at the North Pole over night, and there's ice enough for everybody."

The assistant of the research man, being young in years, declared that he had no interest in public welfare, and was resolved thenceforth to live a life of sin and iniquity.

"Tut, tut!" said his principal, "what unholy thoughts are possessing you?"

"I was raised orthodox," said he, "and I stick to it, with all the fire and brimstone that's in the catechism. And I have concluded to multiply my sins and to land in limbo. With the great heat available I expect to develop a considerable power plant. This will enable me to operate a refrigerating apparatus large enough to provide an equable temperature for my own apartment. The power plant will also serve to drive an electric generator, and this will enable me to bring down the sulphur fumes by the Cottrell method of electric precipitation. With the air thus cleared and the temperature regulated, I look forward to an enviable measure of comfort in hell."

"Just let me know," said the man of research, "when this life of sin and iniquity is to begin for the sake of order in the laboratory, and, by George, we'd better be getting there as fast as we can. We have those determinations to start, you know." The others also had work in hand and so, *exeunt omnes*, into the work-day world, where tasks are set and invention bees are discouraged.

PETER TEN BROECK.

Coming Meetings and Events

American Institute of Metals and American Foundrymen's Association, Foundrymen's Convention, Cleveland, Sept. 11-16.

American Institute of Mining Engineers, Arizona, Sept. 18-23.

Association of Iron and Steel Electrical Engineers, Chicago, Sept. 18-22.

American Peat Society, Washington, D. C., Sept. 21-23.

Mining and Metallurgical Society of America, New York Section, New York, Sept. 21.

Second National Exposition of Chemical Industries, New York, Sept. 25-30.

American Chemical Society, New York, Sept. 25-30.

American Electrochemical Society, New York, Sept. 28-30.

Technical Section, American Paper and Pulp Association, New York, Sept. 25-30.

American Gas Institute, Chicago, Oct. 17-20.

American Society of Mechanical Engineers, New York, Dec. 5-8.

American Institute of Chemical Engineers, New York, Jan. 10-13, 1917.

Edinburgh Meeting of Society of Chemical Industry

The thirty-fifth annual general meeting of the Society of Chemical Industry was held in Edinburgh, Scotland, at the University of Edinburgh, July 19 to 21, 1916, and was devoted to a discussion of the progress of British chemical industries since the war. The Lord Provost of Edinburgh, Sir Robert Inches, welcomed the society to Edinburgh, and recalled the first meeting which the society held in Edinburgh in 1894. The president of the society, Dr. Charles Carpenter, then replied and took the chair. The report of the council was read, giving a review of the meetings of various committees and of the work done during the previous year.

Doctor Carpenter, in his presidential address, expressed his appreciation of the Edinburgh section, the youngest section of the society. He said the "Athens of the North" claimed homage essentially as an ancient seat of learning, a more congenial soil for the study of *belles-lettres* than for researches in dyestuffs. If art and science mutually need inspiration from each other, the meeting in Edinburgh cannot but be fruitful in

good results. The president made a strong plea for a closer relation between science and industry. He urged upon the University of Edinburgh the necessity of placing science in the forefront of its teaching, and thus setting an example to other similar large universities. Engineering and chemistry should go hand in hand to successfully develop chemical industries. The worker also should be given consideration, and profit-sharing plans make for a higher efficiency. Education of the law-makers was also urged, and the establishment of chairs of organic and inorganic chemistry at all universities, new and old. He spoke of the value of chemical meetings, and suggested the building of a permanent meeting house, to contain library, laboratory, etc.

The medal of the society was presented by the president to Mr. C. F. Cross for his services to chemical industry, especially cellulose and paper. During the meeting there was an exhibition of dyes, glass, porcelain, etc., indicating progress made in manufacturing since the war. It was decided to accept the invitation to hold the next meeting at Birmingham.

The following papers were presented:

Fuel Economy: A National Policy Required, by Henry E. Armstrong.

Recent Improvements in By-Product Coke Over Practice, by G. P. Lishman.

Waste in Coal Production, by Henry Louis.

The Shale Oil Industry, by D. R. Steuart.

The Influence of the European War on the Tar Distillation Industry, by W. H. Coleman.

The Extraction of Tar Fog from Hot Gas, by G. T. Purves.

The British Coal Tar Color Industry and Its Difficulties in War Time, by C. M. Whittaker.

The Production of Alkaloids, as Affected by the War, by D. B. Dott.

The Manufacture of Synthetic Medicinal Chemicals as Affected by the War, by Francis H. Carr.

The Manufacture of Fine Chemicals in Relation to British Chemical Industry, by C. A. Hill and T. D. Morson.

The Paper Mill Chemist in War Time, by J. F. Briggs.

The Overhauling of Our Patent Law, by J. W. Gordon.

The Influence of Patent Law Upon Industry, by Walter F. Reid.

The Disadvantage of the Present Patent Law, by W. P. Thompson.

The Progress of the British Rare Earth Industry During the War, by Sidney J. Johnstone.

The Iron and Steel Market

The steel market has continued to make progress toward a still stronger and more active condition. The \$2 a ton advance in bars, plates and shapes made by the Carnegie Steel Company early in August has been followed by all other producers and the market is now on the higher level. For a month that is normally very dull August has done quite well in the matter of new bookings, as the contract obligations written are substantially equal to the shipments. The Steel Corporation's unfilled obligations decreased by 297,340 tons during June, but by only 46,866 tons during July, and the preponderating prediction is that a slight increase will be shown for August.

There has been no excitement in the steel market in the past fortnight, the surface appearance being one of dullness, but tonnage has been booked nevertheless. There has been an export demand greater than could be satisfied as all the deliveries desired could not be compassed by the mills, and some of the domestic consuming trades have been free buyers. The automobile trade has been particularly conspicuous in urging that contracts for deliveries over the first half of 1917 be accepted at once, even though the price might be left open. Assurance of delivery is the prime consideration in this trade. The agricultural implement makers, by way of contrast, have been very conservative in the matter of buying and insist that if steel prices are maintained at their present high level the demand for their product will be greatly reduced.

The report of the Bridge Builders' and Structural Society shows that bookings of fabricated steel contracts in July represented only $47\frac{1}{2}$ per cent of a month's capacity, the smallest percentage reported since February, 1916. Freight car orders have been extremely light. The outstanding feature of the situation is the difficulty in determining how the pressure on the steel mills can be so great when several lines of consumption are decidedly slack.

Averaging the entire period July and August and the entire steel industry there has been hotter weather than in any preceding season since there was a steel industry of any proportions. The weather moreover has had an unusually great effect in cutting down production. The steel mills are but scantily manned at best and as the men are prosperous there has been more disposition to quit work when the temperature was disagreeable. The production of steel in the two months has probably been more than 10 per cent less than the production in the two months preceding.

The Scarcity of Unfinished Steel

A striking feature of the steel situation has been the extreme scarcity of unfinished steel. The billet and sheet bar market has pursued its own course. It increased in strength in 1915 and in the first four months of this year quite in keeping with the developments in finished steel products, but in May it turned somewhat soft and in June there were offerings that were absorbed with such difficulty that the market turned distinctly soft and prices became quotably lower. In July there was some buying in the domestic market, but not a great deal, and there was a moderately heavy export demand. There was continued heavy demand for shell steel, the buying being continued for a much longer period than had been expected. Early in August unfinished steel was suddenly found to be very scarce and the mills practically withdrew from the market. Excited canvasses have been made for steel by both domestic and foreign buyers and in the past fortnight the conviction has been reached that there is practically no soft steel offered, irrespective of price, for any delivery during the remainder of the year. Billets and sheet bars are quotable at \$45 to \$50 but the quotations are nominal. Occasional buyers who have influence and trade connections may be able to secure steel but the average buyer cannot make a purchase. The market has accordingly turned very quiet.

The condition as to unfinished steel is not an ordinary market one, there being no proper relation between unfinished and finished steel Current prices for billets and merchant bars, sheet bars and light gage sheets, do not represent spreads equal to the actual mill cost of conversion. There would be a greater profit to the steel mill in selling billets instead of merchant bars, or sheet bars instead of light gage sheets. Apparently the reason the unfinished steel is not sold instead is that the mills wish to hold their custom and must hold their organizations. If finishing operations are curtailed the men seek employment elsewhere and they could not be replaced until the next depression comes.

Pig Iron More Active

During the past fortnight the pig iron market has come to life. Several fair sized lots of Bessemer and

basic iron have been bought by large steel works, while there has been well distributed buying of foundry and malleable. The buying has been done very quietly, few general inquiries being put out, and the market has been more active than appeared from surface indications. Apparently the buyers feared that higher prices would come to prevail if more interest were shown and as prices have been well established it has not been necessary to depend upon competitive bidding to secure the lowest quotation available. It is characteristic of the pig iron market that general buying movements frequently start in August, and the only explanation for such a development in a month that is regarded in general as a dull one marketwise is that many buyers desire to get under cover before an expected rise occurs. No shortage of pig iron can be regarded as having been developed in the past two months, for while furnace outputs have been reduced by the humidity the consumption by steel mills has been reduced in greater ratio. For the future, however, the majority opinion is that pig iron is destined to grow scarcer as there is little new furnace construction while steel making capacity is being constantly increased. Pig iron prices are substantially unchanged, and indeed there has been scarcely any fluctuation since the first of the year.

While iron ore shipments down the lakes have been heavy thus far this season, fully as heavy as the highest estimates indicated, there are doubts whether the movement can continue of the same proportions. The strike of dock laborers at the head of the lakes has been settled, but the Mesabi range strike continues. Production by the underground mines is only a few per cent of capacity and Mesabi range shipments are from the open pits and from stock piles. The stock piles will hardly stand the drain to the end of the season and in some quarters the suggestion is even made that all-rail shipments may be necessary in the winter. There is demand for ore for puddling and open-hearth furnace use and occasional sales are made at premiums above the regular season prices. Some interest is already being manifested in ore for 1917 and there is talk among ore producers of advancing prices about a dollar a ton, following the advances for the present season of 70 cents on old range and 75 cents on Mesabi ores.

Non-Ferrous Metal Market

Aug. 29.—Most of the metals have become stronger during the last two weeks as the result of renewed buying, especially in copper.

Copper.—Buying by domestic consumers has made a strong market during the last two weeks and Lake and electrolytic are quoted at 27.50c. for September and October delivery. November and December is quoted at 27 to 27.25c., with January and February about ½c. lower. Present smelter production is estimated at from 200,000,000 to 250,000,000 lb. per month. Refinery production is somewhat less. The consumption demand in this country has lately been increasing, and is expected to grow still more. Exports up to Aug. 25 were 25,205 tons of 2240 lb.

Tin.—The tin market has not been so active as some of the others, but has had a strong undertone. Deliveries for September, October and November are hard to obtain, owing to uncertainties regarding permits. Spot tin is quoted at 38.75, with futures for next year selling at 38.25 and higher.

Lead.—Considerable strength has been evidenced in the lead market, due to local and Canadian buying. Foreign buying has not been strong, as the foreign governments are said to be well covered. The Trust price has been put back to 6.50c. New York by two advances, one on Aug. 17 and one on Aug. 18, and independents are asking ¼c. higher than this price.

Spelter.—The situation in spelter at present is quiet and easy. About a week ago considerable buying for export created a strong market, but since then there has been a reaction. Prompt spelter is quoted at 9.30 to 9.55c., with fourth quarter at 8.75 to 9.00. The first of the five units of the new electrolytic zinc refinery at Anaconda is completed and ready for operation. The total capacity will be 70,000,000 lb. per annum.

Other Metals.—There was considerable buying of *antimony* a week ago, but at present the market is dull, with Chinese and Japanese quoted at 13.25 to 13.75c. *Aluminium* is quoted at 61c., *magnesium* at $3.75 per pound, *quicksilver* at $75.00 per flask, *platinum* at $60.00 per ounce, and *silver* at 66¼.

Notes on Metallurgical and Chemical Engineering in Great Britain

(By our London Correspondent.)

Since your issue of April 15, in which a short review of the industrial situation in Great Britain was given, probably the most outstanding feature in the industrial situation is that of the further gradual withdrawal of labor consequent on the calling up of larger groups of men for military service.

Speaking broadly this has been done without disturbance of output, the employment of female labor wherever possible permitting of the change without affecting the general situation.

The abandonment of the Whitsuntide holiday was accepted by the industrial classes in a praiseworthy manner, and a considerable saving thereby effected.

Production of machinery for what may be termed private purposes (*i.e.*, not connected with the war) has not come to a standstill, the cessation of orders being governed as much by waiting on the general situation as by the necessity of standing aside for more urgent work. The withdrawal of labor is probably felt more deeply by the building trades and those dependent on local carriage of goods, such as laundries and small retailers; it is not noticeable in engineering factories. At a pinch there are large numbers of men over military age, and youths just approaching it, who would be willing to undertake work required to set free specialized labor for any purpose of national importance.

The graduated movements of prices in the commodities on the open market is a satisfactory feature.

Attention is continually being drawn to the loss to the community of coal products by the burning of the coal in beehive ovens. Sir William Garforth in his Presidential address to the Institute of Mining Engineers, dwelt upon the need for investigation into this loss. On a conservative estimate 70,000 tons of ammonium sulphate and 12 to 15 million gallons of benzol, as well as tar, could be saved if the coal were distilled in retort ovens. The general interest directed in the direction of saving coal and coal products is a most encouraging symptom at the present time.

Bearing upon the artificial manure question, the Sulphate of Ammonia Association recently gave some interesting figures from an article in the Frankfurter Handelsblatt of May 29th. The Association does not, of course, vouch for the accuracy of the estimates, and considers one or two of the statements to be obviously exaggerated. The article, however, apart from this, is of interest to those who can weigh its statements. A table is first given showing the increase in consumption of nitrate of soda in Germany from 55,000 tons in 1880 to 747,000 tons in 1913. By degrees the imported ar-

ticle has been superseded by sulphate of ammonia, of which 460,000 tons were used in 1913, as against 750,000 tons of nitrate of soda. In order to have a supply of artificial manure nearer than Norway the Badische Aniline and Soda works, unable through lack of water-power to manufacture by the Norwegian process, started a process of their own, called after its originator the Haber process. Production rose from 30,000 tons in 1913 to 60,000 in 1914, and 150,000 tons by the middle of 1916. The production from 1916 onwards is estimated at 300,000 tons. The article further assumes that this output can be increased to 500,000 tons, a quantity equal to the value as manure of the nitrate of soda formerly imported.

The various results supposed to follow on the above by the writers of the article do not seem to be affected by problems of carriage and distribution.

The meeting of the British Association will be for the week following September 5, at Newcastle. The President-Elect is Sir Arthur Evans, F.R.S., who will preside over the Engineering Section.

A valuable paper was recently contributed to the proceedings of the Faraday Society by Mr. Z. Jeffries of Cleveland, Ohio, on "Grain Size Measurements in Metals and the Importance of Such Information."

* * *

Some curious fluctuations have taken place in the prices of metals during the period March-April-May. Tin in comparison with its usual habits, may be said to have been the least active. Starting early in March at £184 it climbed pretty speedily (only two slight drops) to £202 on the 28th. It then dropped to £198 by May 4, and, turning, rose rapidly to £205 on the 8th. Then came a rapid drop of £7 in four days, since which the tendency has been downward, till £187 was reached on May 31.

Considering that the fluctuations on this metal have been confined to £21 or, say 10 per cent, there seems to be nothing sensational about it. Probably the price is so near the top as to have a steadying effect.

Copper on the other hand has shown a remarkable rise in price. Starting in March at a high price £106, it dropped on the order prohibiting speculative dealings in metals of vital importance to £96 by the 9th. Recovering, however, it ran up to nearly £119 in under a fortnight, then lost £4, and ultimately settled down to a steady rise to over £145 on May 17. A rapid drop followed which had landed it at £122 by the end of the month. The total fluctuation was therefore £40, or something like 50 per cent on the normal price.

Lead has also been very active. Even at the extraordinary price of £34 with which it commenced in March, it rose to £36 by the 21st, and only had one drop, to £33 on April 5. A downward tendency commenced about the middle of April, however, which became more pronounced in May, and the metal closed at £32.

Scotch Pig and Cleveland both rose till the middle of April, when Scotch stood at 104/- and Cleveland at 96/-. The end of May saw them at 88/- and 82/- respectively.

Hematite, however, went up and remained up, being quoted throughout March at 115/- and assuming in April a nominal price of 122/-.

Quicksilver was quite steady all through, about £17 per bottle.

* * *

Signor Marconi's promise of a newly invented method of preventing collision at sea shows how the inventive mind may be engaged in its usual activities even when one would suppose it to be sufficiently loaded by the preoccupation and urgent needs of present circumstances. While awaiting with interest the description of the apparatus it may be recalled that Professor Joby has already worked out one method which he described in his book on the subject of Marine Signalling. For shore use this method depends on the transmission of two signals, a sound and a wireless one.

The difference in the time of receiving was the basis from which knowledge of position was worked out. The collision safeguard appeared to be liable to confusion in crowded waters.

* * *

Reference was made to the export of nitrate of soda from the Norwegian fixation factories in a lecture by Mr. E. Kilburn Scott at Birmingham on June 15. He pointed out the need of stimulating the production of ammonia nitrate, and the method by which this might be accomplished.

* * *

The possibility of a shortage of copper in Central Europe inducing a large consumption of Aluminium for Electrical purposes makes a recent article in *L'Information* on the comparative outputs of the metal especially interesting. The writer estimates the combined output of works belonging to England and France at 28,000 tons per annum, and Italy 3000 tons, against 22,000 tons for Germany and Austria. Among the former are deposits at Straun in Iceland and the British Aluminium Company's sources of supply at Glenravel. France has mineral deposits at Bouches du Rhone and the Var. Germany only possesses deposits in Hessen-Nassau, the quality of which does not appear to be up to standard, but these are, of course, supplemented by Austria with products from Styria and Carniola, as well as at Prechora. Previous to the war the Germans had, apparently, been acquiring interests in a company for working the French deposits, but this company has since been placed under sequestration.

* * *

The tendency of investigation in any science to split itself into a number of different branches is again exemplified by the information gained in the study of X-rays. At the meeting of the Roentgen Society on June 6, Prof. J. W. Nicholson read a paper on homogeneity of visible radiation, in the discussion on which Major Robert Wilson pointed out that different results could be obtained by the use of rays obtained from high tension transformers than by the use of the static machine.

Dr. G. W. Kaye, going further into the subject, gave examples showing the lack of homogeneity in X-rays, which appears to open up a very large field for investigation.

* * *

Among the Societies passing resolutions for the exclusion from membership of enemy aliens are the Institution of Electrical Engineers, and the Chemical Society.

Market Prices
June, 1916

	£	s	d
Borax, Brit. refined crystal, cwt	1	10	0
Copper sulphate, ton	53	0	0
Ebonite rod, lb.		3	0
India-rubber, Para fine, lb.		2	5
Mica in original cases, medium	3/6 to 6/		
Quicksilver (Spanish), bottle	16	2	6
Sal-ammoniac, ton	75	0	0
Shellac, cwt.	4	15	0
Nitrate of soda, refined, ton	18	15	0

Copper opened at £121 and rose to £124 on the 5th, thence easier to £107 on the 20th, and £103 on the 26th.

Tin opened £189 and continued down to £183 on the 6th, then recovered to £187.15 on the 9th, but dropped again, reaching £177 on the 20th, and £173.10 on the 26th.

Lead opened £33 and hardened to £33.5, but dropped from the 9th to £32.5 on the 16th, and £30.15 on the 26th.

Cleveland has been 82/6 for home consumption and 100/- for export throughout the month.

Hematite.—No prices available.

Scotch Pig.—122/6 Home, 140/- export.

Second National Exposition of Chemical Industries

The managers of the Second National Exposition of Chemical Industries, to be held at the Grand Central Palace, during the week of Sept. 25, report that most of the space on the second floor has been taken.

To meet the requirements of the societies who will hold meetings at the Grand Central Palace the auditorium has had to be increased in size, so that now it will comfortably seat five hundred persons. An automatic motion-picture machine of the latest design will be used to display the motion pictures, many of which will be loaned by exhibitors. In many cases there will be lecturers to take the audience through a pictorial tour of a plant, and they will be shown machinery and processes in the manufacture of materials. Many of the films are at present being made, and are expected to be finished in time to be shown at the Exposition. A few of these films are as follows:

Making of Black Powder.
Manufacture of Iron.
Manufacture of Fertilizers.
Mining and Manufacturing of Iron.
Manufacturing of Silk.
Making of Blotting Paper.
Silver Mining.
Manufacturing of Varnish.
Asphalt.

Two other features of the Exposition that have been added this year are a large section showing the opportunities that await the chemist in our South, and known as the "Southern Opportunity Section," and a section for the "Paper and Pulp Industry," composed of materials and machinery used in the manufacture of paper and other related products.

The "Southern Opportunity Section" was formed to display to our chemists, chemical engineers and capitalists the great latent wealth that awaits them in the undeveloped resources of the South.

The Bureau of Mines is preparing an elaborate exhibit that will cover much space; it will be a working exhibit, one where the visitor can see actual operations being carried on.

The members of the American Chemical Society and the American Electrochemical Society who register with their societies will receive badges. These will admit them to the exposition without further tickets.

The following list comprises concerns which have taken space at the Exposition up to the time of going to press:

Abbe Engineering Company
Abbe, Paul O.
American Chemical Society
American Electrochemical Society
American Coal & By-Products Coke Company
American Institute of Mining Engineers
Angel & Company, H. Reeve
Badger & Sons Company, E. B.
Baker, J. T., Chemical Company
Barrett Company, The
Bausch & Lomb Optical Company
Benzol Products Company
Bethlehem Foundry & Machine Company
Boston Artificial Leather Company
Brown Instrument Company
Buffalo Foundry & Machine Company
Carborundum Company
Carrier Engineering Company
Celluloid Zapon Company
Codd Company, E. J.
Condensite Company of America
De Laval Separator Company
Detroit Range Boiler Company
Devine Company, J. P.
Dorr Company
Dow Chemical Company
Driver-Harris Wire Company
DuPont, E. I., DeNemours Company.
Duriron Castings Company
Edison, Thomas A.
Eimer & Amend
Electro Bleaching Gas Company
Elyria Enameled Products Company
Foote Mineral Company
Freeport Sulphur Company
Geissinger Regulator Company
General Bakelite Company
General Chemical Company
German-American Stoneware Company
Glens Falls Machine Works
Great Western Power Company
Greiner Company, Emil
Hardinge-Conical Mill Company
Herold China & Pottery Company
Huff Electrostatic Separator Company
International Equipment Company
International Filtration Corporation
International Glass Company
Kieselguhr Company of America
Koppers Company, H.
Koven & Bro., L. O.
Laboratory Supply Company
Lead Lined Iron Pipe Company
Leeds & Northrup Company
Lenz & Naumann, Inc.
Little, Arthur D., Inc.—Boston
Little, Arthur D., Ltd.—Montreal
Lungwitz, Emil E.
Luzerne Rubber Company
Marden, Orth & Hastings Company
Merck & Company
Metallurgical & Chemical Engineering.
Monsanto Chemical Works
Mott, J. L., Iron Works
Multi-Metal Sep. Screen Company
National Aniline & Chemical Company.
National Gum & Mica Company
Niagara Alkali Company
Norton Company
Ohio Pottery Company
Palo Company, The
Patterson-Allen Engineering Company
Pfaudler Company
Precision Instrument Company
Raritan Copper Works
Raymond Bros. Impact Pulverizer Company
Research Corporation
Ruggles-Coles Engineering Company
Schaeffer & Budenberg Manufacturing Company
Schaum & Uhlinger, Inc.
Schutte & Koerting
Scott & Company, Ernest
Scientific Materials Company
Semet-Solvay Company
Sharples Specialty Company
Sidio Company of America
Solvay Process Company
Sowers Manufacturing Company
Squibb & Sons, E. R.
Stamford Manufacturing Company
Standard Aniline Products, Inc.
Stevens-Aylsworth Company
Sturtevant Mill Company
Sweetland Filter Press Company
Swenson Evaporator Company
Taylor Instrument Company
Technical Association of Paper & Pulp Industry
Tennessee Power Company
Thermal Syndicate, Ltd.
Thwing Instrument Company
Toch Brothers
Tolhurst Machine Works
Uehling Instrument Company
Union Sulphur Company
United Lead Company
United States Smelting Company
Valley Iron Works
Weiller Manufacturing Company
Werner & Pfleiderer Company
West Pulverizer Machine Company
Williams Patent Crusher & Pulverizer Company
Zaremba Company

American Transformer Company
American Synthetic Color Company
Alberene Stone Company
Barber Asphalt Paving Company
Wm. Beckers Aniline & Chemical Works
The Bristol Company
Bureau of Mines
Central Foundry Company
Chemical Catalog Company
Chemical Company of America
Coatesville Boiler Works
Corning Glass Works
Castner Electrolytic Alkali Works
J. H. Day Company
Denver Fire Clay Company
Downingtown Manufacturing Company
Electro Chemical Company
Electron Chemical Company
The Foxboro Company
General Electric Company
Harrison Bros. Company
Frank Hemingway Corporation
Hooker Electrochemical Company
F. C. Huyck & Sons
Krebs Pigment & Color Company
F. Kleinschmidt & Company
Life Saving Devices Company
Lehigh Car Wheel & Axle Works
Manufacturers' Record
Mathieson Alkali Works
Mine & Smelter Supply Company

Mississippi River Power Company
Nash Engineering Company
Nitrogen Products Company
Newport Chemical Works, Inc.
Paper, Inc.
Paper Trade Journal
Pennsylvania Salt Manufacturing Company
Process Engineers, Ltd.
Pyrolectric Instrument Company
Roessler & Hasslacher Chemical Company
Seydel Manufacturing Company
Stone & Webster Engineering Corporation
Shriver & Company, T.
Swiss Colours Company
Stuart & Peterson Company
Society of Chemical Industry
United Gas Improvement Company
U. S. Standard Chemical Works

New York Meeting of American Electrochemical Society

The thirtieth general meeting of the American Electrochemical Society which will be held in conjunction with the Exposition of Chemical Industries during the week of September 25 to 30, will be opened on Thursday, Sept. 28, with the "Made in America" technical session. The complete program of technical and business meetings and of entertainment features will be given in our next issue. The ladies' entertainment features will be found in the adjoining program of the ladies' committee. Members of the Electrochemical Society will register at the Society's booth at the Exposition. The complimentary smoker on Thursday evening and the joint banquet on Friday evening with the American Chemical Society and Technical Association of the Paper & Pulp Industry promise to be real live entertainment features. Other entertainment features will be announced later, together with the complete technical program.

Program of Ladies' Committee of American Chemical Society and American Electrochemical Society

The following program has been arranged for visiting ladies by the ladies' committee of the American Chemical Society and American Electro-Chemical Society for the New York meetings during the week of Sept. 25. The lady in charge of each event is included.

Monday and Tuesday—Welcoming the visiting ladies at the registration rooms—(Chemists' Club). Mrs. Frank Hemingway.

Visiting the Chemical Industries Exposition. Mrs. Bernard C. Hesse.

Tuesday—8.00 p. m. Reception at Hotel Astor.

Wednesday—10.30 a. m. Meeting—Chemists' Club, for an automobile tour along the Hudson. Mrs. J. Merritt Matthews.

1.00 p. m. Luncheon at Longview, Hastings-on-Hudson. Return to New York 5.00 p. m. Mrs. J. Malcom Muir.

Thursday—10.30 a. m. Meeting—Chemists' Club for a visit to Altman's and Tiffany's stores. Mrs. R. N. Shreve.

1.00 p. m. Luncheon at the Woman's City Club and at the University Club. Mrs. R. N. Shreve.

8.00 p. m. Theater party—Complimentary to visiting ladies only.

Friday—2.00 p. m. Seeing New York Yacht Party. Mrs. Charles Baskerville.

8.00 p. m. Banquet.

Saturday—Visiting Chemical Industries Exposition. Mrs. Bernard C. Hesse.

The ladies' committee, including those who have joined up to the present time is as follows: Mrs. L. H. Baekeland, in charge; Mrs. Milton C. Whitaker, Mrs. Bernhard C. Hesse, Mrs. Jerome Alexander, Mrs. Morris Loeb, Mrs. Charles Baskerville, Mrs. J. Merritt Matthews, Mrs. Parker C. McIlhiney, Mrs. Frank Hemingway, Mrs. T. B. Wagner, Mrs. Elon H. Hooker, Mrs. Charles H. Herty, Mrs. Charles L. Parsons, Mrs. Herbert R. Moody, Mrs. R. N. Shreve, Miss Leola Maars, Miss E. H. Kunz, Mrs. Maximillian Toch, Mrs. J. Malcom Muir, Mrs. Eugene F. Roeber, Mrs. Colin G. Fink, Mrs. A. B. Marvin, Mrs. Lawrence Addicks, Miss Agnes Hasslacher, Mrs. J. V. N. Dorr.

Cleveland Meeting of American Institute of Metals

The annual meeting of the American Institute of Metals will be held in Cleveland, Sept. 11-15, together with the convention of the American Foundrymen's Association. The annual foundry exhibition will be held in the Coliseum, and indications point to a much larger exhibit than was shown at Atlantic City last year. There will be many interesting entertainment features, including a trip to the ball park Tuesday afternoon, Sept. 12, for the game between Cleveland and Detroit; a trip to Euclid Beach Park Tuesday evening in special cars, tickets being furnished to all concessions; an inspection trip Wednesday afternoon to the Cleveland Furnace Company's blast-furnace plant on the Cuyahoga River flats, and entertainment at Keith's Hippodrome Wednesday evening. A luncheon will be given the ladies at the Hotel Statler, and on a later day an automobile ride. The annual banquet will be held Thursday evening, at the Statler, with Irving Bacheler as one of the speakers. Plant visitation will be limited to Thursday and Friday. Arrangements have been made for the inspection of the plants of the Ferro Machine & Foundry Company, Allyne-Ryan Foundry Company and Westinghouse Electric & Mfg. Company.

Following is a list of some of the papers which will be presented:

"Reclamation of Metallics from the By-Products of Foundry and Manufacturing Plants," by A. F. Taggart.

"Method of Selling Non-Ferrous Scrap, as Pursued by a Large Producer," by J. M. Bateman.

"The Result of Joint Work of Casting and Testing the 88-10-2 Alloy by Five Foundries, Report of the Use of the Deoxidizers of Bronzes and Report on the Aspects of Bronze Failures," by various experts affiliated with the U. S. Bureau of Standards, Washington, D. C.

"Copper-Aluminum-Iron Alloys," by W. M. Corse.

"Tests on Rolled Brass Sheets Taken in the Direction of Rolling and at Right Angles to the Direction," by W. B. Price and P. H. Davidson.

"The Application of Oxy-Acetylene Welding Process in the Repair of Defective Non-Ferrous Castings," by S. W. Miller.

"Continuation of Discussion in Connection with Defective Bronze Castings in Use by the Board of Water Supply of New York City," by A. D. Flinn.

"Evolution of Die Casting Process," by Charles Pack.

"Disclosure of Blowholes by Means of X-Ray Apparatus," to be reported by testing engineers employed in laboratory D of the General Electric Company, Schenectady, N. Y.

"Aluminum Castings and Forgings," by P. E. McKinney.

"Annealing Properties of Copper," by G. W. Ceaser and G. C. Gerner.

"Metallography as Applied to Non-Ferrous Metals," by W. W. Arthur.

"Heat Treatment of German Silver," by G. C. Holder.

Rubber Vulcanization Accelerators

BY ANDREW H. KING

This is a subject now attracting considerable attention in the rubber business. The possibilities seem almost unlimited. For example, a factory which has been using the old, well-known mineral accelerators can materially increase its capacity by the use of some one or more of the new organic catalysers, such as piperidine or para-phenylenediamine.

It is common knowledge that the degree of vulcanization can be greatly influenced by a change in either time or temperature. Thus a stock which cures ordinarily in 40 minutes at 40 lb. steam pressure can be vulcanized in 25 minutes at 60 lb. This is one way to speed up production. However, the increase in working steam pressure is expensive, and sometimes quite unsatisfactory. It is far better to add from 1 to 2 per cent of some good accelerator, and properly cure the rubber at low pressure, than to run chances of injuring the nerve by high temperature. In certain instances both high temperatures and accelerators are used, as in the case of cheap molded goods, where a large production is necessary to take care of the overhead.

An accelerator is merely a catalyser. It tends to increase the velocity of the reaction between sulfur and rubber during vulcanization. For the sake of clearness, I will enumerate a few conclusions deduced from numerous observations of the catalytic effect, sometimes called "the laws of catalysis":

1. The catalyser has the same chemical composition at the end of the reaction as it had in the beginning. This statement applies to nearly all accelerators, except certain of the organic compounds which are decomposed to a more or less extent at the temperature of vulcanization.

2. A catalytic agent is incapable of starting a reaction. It can only modify the velocity.

3. Very small quantities are sufficient to transform relatively large amounts of reacting substances.

4. The final state of equilibrium is independent of the nature and quantity of a catalyst.

5. Catalysers are of two kinds—positive and negative; *i.e.*, they may either increase or retard the reaction velocity.

The above statements are based on observed facts. Just why they are so, and what the underlying principle of catalysis is, the future may explain. There are numerous theories which seem to fit separate cases quite well. Thus, the theory of surface concentration seems an excellent explanation of the behavior of platinum sponge in the contact process for sulfuric acid.

But the separate group of vulcanization accelerators seem to belong to the intermediate product family. It is thought that the catalyser unites with one of the reacting substances, forming an unstable compound, which in turn reacts with the other substance. In the course of this reaction, the catalyser is set free, and the process begins all over again.

An example of this phenomenon, though not a catalytic action in the true sense, is found in the commercial method for the preparation of aniline. Nitrobenzole is reduced by means of iron filings and hydrochloric acid. Only about one-fortieth of the theoretical quantity of acid is necessary. This is probably because iron filings and water are able to effect the reduction in the presence of ferrous chloride. In this instance it may be called a pseudo-catalyser. The reactions taking place are sometimes written as follows:

(1) $C_6H_5NO_2 + 3Fe + 6HCl \rightleftarrows 3FeCl_2 + 2H_2O + C_6H_5NH_2$.

(2) $FeCl_2 + 2C_6H_5NH_2 + 2H_2O \rightleftarrows Fe(OH)_2 + 2C_6H_5NH_2, HCl$.

(3) $2C_6H_5NH_2HCl + Fe \rightleftarrows FeCl_2 + H_2 + 2C_6H_5NH_2$.

(4) $C_6H_5NO_2 + 3H_2 \rightleftarrows C_6H_5NH_2 + 2H_2O$.

The halogen carriers, which are so important in organic preparations, are also pseudo-catalysers.

The chemical reaction between sulfur and rubber may be written:

$$\text{Sulfur} + \text{Rubber} \leftrightarrows \text{Polyprene Sulfide.}$$

The speed of this reaction is influenced in proportion to the quantity of accelerator used, up to a certain limit, beyond which it acts as a retarder; that is, as a negative catalyser. As a general rule, accelerators should be used in small amounts, so as not to affect the nerve or quality of the rubber.

A peculiar fact has been noted. By a combination of accelerators the resulting increase in speed is greater than the sum of their individual increases, when acting alone. For example, the effect of 1 per cent tetramethylenediamine and 1 per cent piperidine exceeds the sum of the effects of the same catalysers when mixed in separate batches.

MINERAL ACCELERATORS

The chief mineral accelerators are:

Lime
Magnesia
Litharge
White lead
Zinc oxide

They are named in the order of their relative power.

Lime: The lime in common use is prepared by burning limestone and slacking the product by means of steam. Properly prepared, it is just a little short of complete hydration. In curing soft rubber from ½ to 2½ per cent may be used. For hard rubber larger amounts are customary.

Magnesia: The best magnesia is a heavy calcined product known as "Magnesia Usta." It is prepared by precipitating magnesium from solution in the form of magnesium carbonate and calcining the product. Magnesia finds a larger use than lime, though its curing action is only about half as great. Its advantage is that it leaves the nerve of the rubber absolutely unaffected, while lime has a slight hardening action. Combined with litharge it produces very satisfactory results.

Litharge and other lead compounds: Besides litharge, such compounds as white lead, sublimed white lead, and red lead are also valuable. Their use is limited, however, to black goods, and to those having high specific gravities. Stevens (J. Soc. Chem. Ind., 34, 524-6, 1915) is of the opinion that the catalytic effect of litharge is due to the heat liberated by the following reaction:

$$4PbO + 2S_2 \rightleftarrows 3PbS + PbSO_4$$

This effect is proportional to the quantity present, so long as there is sufficient sulfur available to properly cure the rubber, and to convert the litharge to lead sulfide and sulfate. About 1 per cent sulfur is required for every 7 per cent of litharge. At the point where the rubber is fully cured the free sulfur drops, but is never completely absent. Large amounts of litharge serve to prevent "blooming"; *i.e.*, the coming to the surface of colloidal free sulfur in the form of a gray scum.

Red lead is more active than litharge, but should never be used because of its oxidizing tendency. White lead, that is basic lead carbonate, is also an accelerator. Compared with litharge it has a much lower specific gravity and considerable toughening action. Sublimed white lead has the following average composition:

$PbSO_4$	78.5%
PbO	16.
ZnO	5.5

It has only slight curing action, but is also a good toughener.

Zinc oxide: This has but little accelerating power. As a toughener it surpasses all of the lead fillers, and is only exceeded in this respect by lamp black. Because of its slight catalytic effect, considerable quantities can be used without retarding the cure.

Miscellaneous: Some oxides have a catalytic action under special circumstances. Thus, iron oxide (3 to 8 per cent) is quite useful in batches containing brown substitute.

Golden antimony sulfide also finds considerable use. It has but small catalytic value. Its action is due mainly to free sulfur, which the technical product always contains.

Manganese oxide, MnO, and cuprous oxide, Cu_2O, are both good accelerators, but because of their marked oxidizing tendencies they cannot be used. In fact, as a general rule copper and manganese, in any form, must be kept out of rubber if the product is to be anything but worthless.

Molybdenum sesqui-oxide over 10 per cent and alkali over 3 per cent are negative accelerators. The behavior of alkali is especially interesting, owing to the extensive use of alkali shoddies. Up to ½ per cent it acts as an accelerator. Beyond this it retards, and at 5 per cent it is almost impossible to effect a cure. Nickel oxide is a negative accelerator, and vulcanization can be entirely prevented by its use.

ORGANIC ACCELERATORS

The use of organic accelerators dates from the discovery of synthetic rubber. This product cannot be vulcanized without the addition of some of the organic catalysers. On the substitution of natural for synthetic rubber equally successful results were obtained.

The trouble with synthetic rubber, and for a time with the plantation variety, was excessive cleanliness. They secured the rubber hydrocarbon, but certain so-called impurities, which Mother Nature places in the rubber latex, were carefully excluded. Para rubber, by the Amazon method of coagulation, contains all the elements of the latex evenly distributed throughout the mass. For this very reason it is still true that no rubber is the equal of Highlands Fine Para.

The catalysers present in rubber latex are thought to be related to the proteins, perhaps decomposition products. All organic accelerators are nitrogen bearing, and many have amino groups. The function of the nitrogen seems very important. So far there are only two generalizations possible:

1. According to Ditmar, all organic bases having dissociation constants greater than 10^{-8} act as accelerators, irrespective of constitution.

2. At present only nitrogen bearing compounds are known as accelerators, and it seems that this element must be a necessity.

From a mechanical standpoint a catalyzer is most conveniently mixed when it has the following properties:

It should be a solid, capable of being very finely pulverized.

It should have a high boiling point, so as not to be vaporized during vulcanization. Such behavior would cause a spongy appearance; that is, "blowing."

For convenience I will classify the most important organic accelerators under the following heads:

1. Carbon bisulfide addition products with
   - (a) Aniline
   - (b) Dimethyl aniline
   - (c) Tetrahydropyrrole
   - (d) Dimethylamine
2. Ammonium compounds
   - (a) Ammonium borate
   - (b) Aldehyde ammonia
   - (c) Quaternary ammonium bases
3. Amino compounds
   - (a) Para-phenylenediamine
   - (b) Tetramythylenediamine
   - (c) Sodium amide
   - (d) Naphthylene diamine
   - (e) BB Dimethyl Δ methyltrimethyleneimine
   - (f) Trimethyleneamine
   - (g) Benzylamine
4. Piperidine and derivatives
   - (a) Piperidine
   - (b) Methyl piperidine
5. Quinoline and derivatives
   - (a) Quinoline
   - (b) Quinoline sulfate
   - (c) Quinosol
   - (d) Sulfuroxyquinoline
6. Miscellaneous
   - (a) Anthraquinone
   - (b) Urea derivatives
   - (c) Formanilides

CARBON BISULFIDE ADDITION PRODUCTS

With Aniline: One of the oldest accelerators known in this country is diphenylthiourea, or thiocarbanilide,

$$C{=}S\begin{matrix}\diagup NH, C_6H_5\\ \diagdown NH, C_6H_5\end{matrix}$$

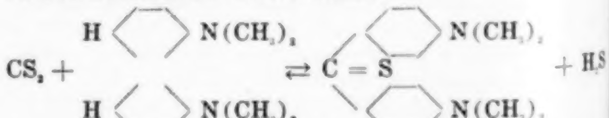
This substance may be prepared according to Gatterman as follows:

A mixture of 40 parts aniline, 50 parts carbon bisulfide, 50 parts of alcohol, and 10 parts of finely powdered potassium hydroxide are boiled gently on a water bath for three hours in a flask provided with a reflux condenser. Excess carbon bisulfide and alcohol are distilled off, and the residue treated with water. The crystals separating out are filtered off, washed first with water, then with dilute hydrochloric acid, and finally with water. To obtain the pure substance, recrystallization from alcohol is necessary. Large colorless tablets are obtained, which melt at 154 deg. C. A very satisfactory, and, in fact, a more desirable, product for use as an accelerator is secured by the substitution of sodium polysulfide Na_2S_x for caustic potash in the above reaction. A high degree of purification is unnecessary. At some factories the aniline, carbon bisulfide, and sodium polysulfide are mixed in large kettles in the open air. After a short time the whole mass solidifies. This is broken up, vacuum dried, and finely ground. A fairly satisfactory product is thus secured. The reaction taking place in this preparation may be written as follows:

$$CS_2 + 2C_6H_5NH_2 \rightleftarrows C{=}S\begin{matrix}\diagup NH.C_6H_5\\ \diagdown NH.C_6H_5\end{matrix} + H_2S$$

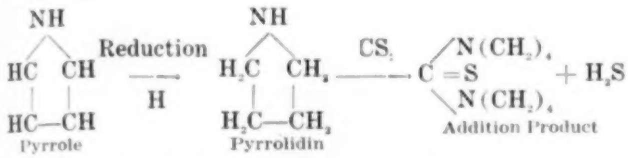
This substance is a very efficient catalyser. It seems to do all of its work at the beginning of the reaction, so that it finds considerable use in quick curing stocks. One-half to 3 per cent is customary.

With Dimethyl Aniline: Carbon bisulfide also forms an addition product with this substance. The reaction here is similar to that of aniline.



With Tetrahydropyrrole: This substance $(CH_2)_4NH$, called by the German chemists "pyrrolidin," is secured

by the reduction of pyrrole, C_4H_5N, by means of zinc dust and hydrochloric acid. Pyrrole is closely related to the proteins, and its derivatives have been isolated from protein decomposition products. The reactions for the preparation of the addition product may be indicated as follows:



With Dimethylamine: As would be suspected, dimethyl amine, $(CH_3)_2NH$, gives an active addition product, whose constitution may be written: $C{=}S$ with two $N(CH_3)_2$ groups.

AMMONIUM COMPOUNDS

Ammonium Borate: Ditmar (Gummi Zeitung, Jan., 1915) mentions the fact that ammonium borate has a noticeable effect on the cure. This is merely of scientific interest.

Aldehyde Ammonia: This is a very satisfactory catalyser. A mixture of 100 parts Para, 10 parts sulfur, and 1 part aldehyde ammonia may be cured in 30 minutes at 45 lb. steam pressure (140 deg. C.). For comparison, a batch of 90 parts Para, 9 of sulfur, and 1 of lime requires 85 minutes at 140 deg. C.

Aldehyde ammonia, $CH_3.CH(OH)NH_2$, is best prepared by passing dry ammonia gas into a solution of acid aldehyde, $CH_3.CHO$ in ether. The reaction is as follows:

$$CH_3CHO + NH_3 \rightleftarrows CH_3CH(OH)NH_2$$

It is readily soluble in water, sparingly so in alcohol, and almost insoluble in ether. It melts between 70 and 80 deg. C., and sublimes without decomposition at 100 deg. C.

Quaternary Ammonium bases: These are mentioned in Bayer & Co.'s British patent 12,661 of May 22, 1914, along with aldehyde ammonia, para-phenylenediamine, sodium amide, benzylamine, and naphthylenediamine.

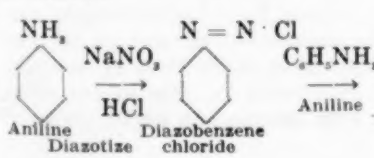
AMINO COMPOUNDS

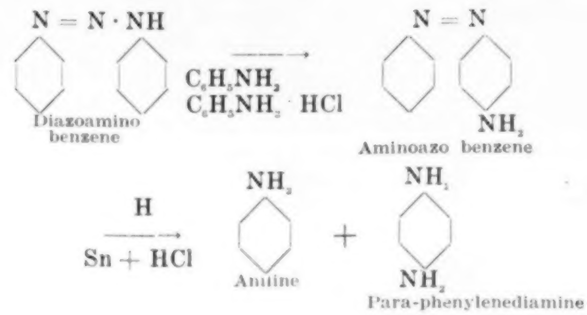
Para-phenylenediamine: This accelerator gives good results with synthetic rubber. Bayer & Co. mention in their German patent 280,198, Jan. 1, 1914, that 100 parts isoprene rubber completely cures when mixed with 10 parts sulfur and 2 parts para-phenylenediamine and is heated in a press for 15 minutes at 45 lb. steam pressure.

Para-phenylenediamine, $C_6H_4(NH_2)_2$;

is produced by reduction of para-nitrobenzene, para-nitroaniline, or of aminoazobenzene with tin and hydrochloric acid. Other methods are: By the distillation of diamino benzoic acid. By the action of para-chloraniline on aqueous ammonia in the presence of copper salts.

Perhaps the simplest method is that for reducing aminoazobenzene. The reactions for its preparation from aniline follow:





This method is the most satisfactory, and relatively cheap. Gatterman may be followed for the preparation of aminoazobenzene. After reduction, distill off the aniline with steam. The product may be purified by fractional crystallization. Pure para-phenylenediamine melts at 140 deg. C., sublimes without decomposition at 267 deg. C., is very soluble in alcohol and ether, and moderately so in water. Manganese dioxide and sulfuric acid convert it to quinone, $C_6H_4O_2$. On passing hydrogen sulfide through a solution of the chloride, and then adding ferric chloride, thionine or Lauth's violet is produced. These tests will indicate the purity of the commercial article.

It should be mentioned that para-phenylenediamine, as likewise most organic accelerators, is very poisonous, and proper precautions should be taken in every case.

Tetramethylenediamine: This substance is mentioned in French patent 464,533 by Bayer & Co. It gives very good results when the desired time of cure is rather long.

Tetramethylenediamine, $NH_2(CH_2)_4NH_2$, called sometimes putrescine, is a natural product of protein decomposition, and is produced during the putrefaction of animal matter, such as flesh.

Dimthylene bromide, $Br.CH_2.CH_2.Br$, is converted by treatment with potassium cyanide to dimethylene cyanide, $NC.CH_2.CH_2.CN$. On reducing this substance with sodium and boiling alcohol or by electrolytic methods, tetramethylene diamine is secured.

$$NC.CH_2.CH_2.CN + 8H \rightleftarrows NH_2(CH_2)_4NH_2.$$

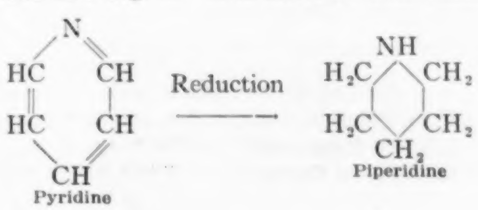
The crystals melt at 270 deg. C. and boil at 157 deg. C.

Miscellaneous Amines: Sodium amide, $NaNH_2$; naphthylenediamine, $C_{10}H_6(NH_2)_2$; trimethylene amine, $(CH_3)_3N$; benzyl amine, $C_6H_5.CH_2.NH_2$; ββ dimethyl Δ trimethyleneimine; and nitrosodimethyl animethylline are mentioned as having some accelerating power.

PIPERIDINE AND DERIVATIVES

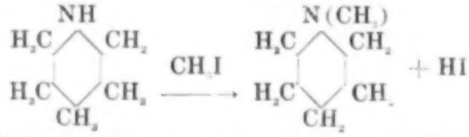
The first patent granted for an organic accelerator was to Bayer & Co. (German patent 265,221, Nov. 16, 1912) for the use of piperidine. As above mentioned, it was intended to be used with synthetic rubber, but proved so successful that it was tried with the natural variety. A mixture of 100 parts Para, 10 parts of sulfur, ½ part piperidine, is perfectly cured on heating for 15 minutes at 53 lb. steam pressure. Without the accelerator over an hour is required. Piperidine is valuable for both hard and soft rubber articles.

Piperidine, $C_5H_{10}NH$, belongs to the class of secondary amines. It is a liquid smelling like pepper and ammonia. It boils at 105.7 deg. C., and has a specific gravity of .881 at 0 deg. C. It is miscible with water in all



proportions. It is best prepared by reduction from pyridine, either by use of sodium in absolute alcohol or by electrolytic methods (E. Merck, English Pat. 21,471). The reaction is as given on the preceding page.

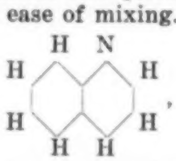
Methyl piperidine: This substance, $C_5H_{10}N(CH_3)$, is also active as a catalyser. It may be prepared by treating piperidine with methyliodide, when the amino hydrogen is replaced by the methyl group.

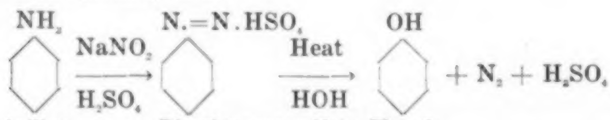


Methyl piperidine is also a liquid, and boils at 107 deg. C.

QUINOLINE AND DERIVATIVES

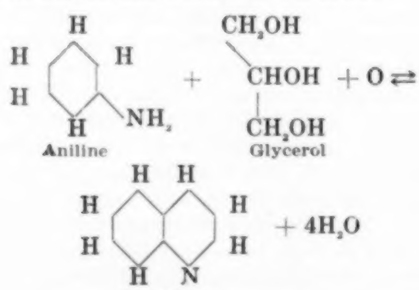
Quinoline and its derivatives are satisfactory accelerators. The amount used varies around 2 or 3 per cent. Perhaps its sulfate and quinosol find the greater application owing to ease of mixing.

Quinoline C_9H_7N,  , may be considered as a combination of a benzene and pyridine ring. It is most satisfactorily prepared by Skraup's synthesis; to a mixture of 19 parts aniline, 12 parts nitrobenzene and 60 parts glycerol; 50 parts of concentrated sulfuric acid are added. Heat under a reflux condenser until reaction begins. Discontinue. When the energetic reaction is over, heat on the water bath for three hours. Cool, dilute with water, steam distill to remove any unchanged nitrobenzole. Make alkaline, steam distill off the liberated quinoline and any unchanged aniline. Considerable of the aniline can be removed by fractional distillation. The remainder is removed by diazotizing in sulfuric acid solution and boiling. This converts the aniline to phenol, thus:



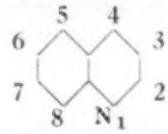
Aniline Diazobenzene sulfate Phenol

Quinoline, being a tertiary amine, is not affected. On making alkaline phenol goes into solution, and quinoline is liberated. It can now be removed by steam distillation, after which it is fractionated in order to obtain the pure substance. The reaction for the production of quinoline is sometimes written as follows:



The oxygen required is supplied by nitrobenzole in a manner not quite clear.

Quinoline, sometimes written $C_6H_4 \left< \begin{matrix} CH : CH \\ N = CH \end{matrix} \right.$ has a sp. gr. of 1.0947 at 20 deg. C. It boils at 240 deg. C., is soluble in alcohol and ether, but only sparingly so in water. It has a disagreeable, penetrating odor, a bitter, acrid taste, and on exposure to moist air is converted to the hydrate, $C_9H_7N + 1\frac{1}{2}H_2O$. The nomenclature of quinoline derivatives is indicated by the scheme



Quinoline sulfate: This is sometimes called quinoline sulfonic acid. For this purpose the 8-acid is most commonly used. It is secured on heating with concentrated sulfuric acid at 220 to 230 deg. C. for a short time. Perhaps the potassium salt of this acid would give better results.

Hydroxy quinoline: This quinoline derivative should be valuable as an accelerator. It may be prepared by the fusion of the 8-quinoline sulfonic acid with caustic potash. It forms prismatic needles melting at 76 deg. C., and boils at 266.6 deg. C. under 752 mm. pressure. It is sparingly soluble in cold water, readily so in alcohol, and volatile with steam. Aqueous solutions of its acid and alkali salts are yellow.

Quinosol: This is 8-hydroxy quinoline, 5-sulfonic acid, and is prepared by sulfonating 8-hydroxy quinoline with cool, fuming sulfuric acid. (Claus and Posset, J. pr. Chem. 1890, 2, 41, 33). Thorpe (Dict. App. Chem. vol. IV, 471) prepares it by heating 8-hydroxy quinoline in alcoholic solution with potassium pyrosulfate, $K_2S_2O_7$. Quinosol forms small sulfur yellow needles, melting 175 to 177.50 deg. C. It is soluble in alcohol and in water.

Ditmar mentions oxyquiniline sulfide as a very satisfactory accelerator.

MISCELLANEOUS

Anthraquinone, 3 to 5 per cent is recommended for use in batches containing substitute.

Urea and such derivatives as guanidine are advised.

There are numerous patents covering the various anilides, such as formanilide, etc. Formanilide, $C_6H_5.NH.CH : O$, is prepared from aniline and formic acid. On treatment with diphosphorpentasulfide, P_2S_5, thioformanilide is produced, $C_6H_5.NH.CH : S$.

Albumen: An interesting consideration is the patent of W. Esch (German patent 273,482, Nov. 22, 1912), which covers the direct addition of proteins to rubber. He first prepares a paste by mixing the protein, usually egg albumen, 15 parts, with 2 parts hydrated lime or magnesium hydroxide. This paste is mixed with the rubber, dried, sheeted, and smoked, to render the albumen insoluble. Low-grades are considerably improved.

CONCLUSION

To the casual reader this paper must appear rather rambling. I have only been able to touch the high spots in the subject of accelerators. In fact, only the high spots are known. As is customary with most great advances, the untrained investigator tries everything he can possibly think of. The theoretical man follows in his path, and adds his discoveries to the great mass of accumulated facts called "Science." The whole subject of rubber is one demanding scientific treatment. The velocity of the reaction between sulfur and rubber should be investigated more thoroughly and from the standpoint of the physical chemist. In fact, a consideration of this subject along the line of the phase rule would doubtless prove as valuable here as it did in the steel industry.

To the novice in this field patience is most necessary. No substance should be rejected until it has been tried under all possible conditions, and in all possible variations. In this, as in other lines of scientific research, the motto must always be, "Go as far as you can see, and then see how far you can go."

Commercial Considerations Concerning the Blast Furnace

BY J. E. JOHNSON, JR.

The object of operating a blast furnace is to make money. This obvious fact should not require to be stated but as a matter of fact for various reasons it is sometimes apparently forgotten by those who operate, and even more frequently by those who build blast furnaces. There seems to be a certain fascination about the business which inspires in those who are not familiar with it the desire to enter it and were this not balanced by an even more acute desire on the part of many of those who are in to get out, the business would be overcrowded worse than it is.

Under these conditions it seems desirable to set forth something of the commercial considerations which must govern in the long run, not only for the benefit of the owner or investor, but equally for the higher employees, for if the business is not fundamentally sound they will have an unhappy time and very likely lose the ultimate benefits of many years of hard work.

Location

This is a subject concerning which much has been written and sometimes without consideration of all the factors. There is probably no other large business in which freight on raw materials and finished product plays so great a part. It may be doubted whether freight is less than 25 per cent of the total cost delivered to the consumer except in a small percentage of the business, it is frequently more than 33 per cent and even 50 per cent. Under such conditions the question of location in relation to sources of raw materials and markets is vital.

In the "Engineering and Mining Journal" of March 13, 1915, I treated this subject on lines which are believed to be new, and developed the law on which the location of the industry seems to hinge, for it accounts for the facts as no other law seems to do. This article is quoted below.

"The reasons generally assigned for the location of the iron industry have dealt chiefly with the question of whether the ore, of which about two tons are required per ton of iron, should be brought to the coal, of which about 1½ tons are required, or vice versa. The coal is frequently coked before shipment and the weight of coke required is only about one ton per ton of iron against nearly twice as much for the ore; but many plants have been located much closer to the coal than the ore, nevertheless. This fact has not unnaturally troubled many who have attempted to work out the underlying causes.

"It may be freely admitted that the location of iron-manufacturing centers is a matter of freight charges; but not, as is commonly assumed, of freight on raw material only. Obviously there must be included freight on the finished product to the point of consumption. If we were to consider the establishment of an iron works in a country entirely without such works, knew that each person would consume a given weight of iron per year, and knew also the tonnage of the proposed works, we should know how much population was required to consume the product and from the density of the population in the country we could calculate the average distance the product would have to be hauled to reach the consumer, and the freight for this haul added to the freight on the raw materials would constitute the total freight charge on the product. It is this which should be kept a minimum. It would clearly be an accident if the point which gave the lowest combined value for the three were at either the ore mines or the coal mines.

"The correct location would obviously be the equilibrium point of the three forces acting through the coal mines and the ore mines and the center of population. We could, without much trouble, make a model which would illustrate the action almost perfectly. We need only to put a peg at the center of population on the map of a given district and one each at the ore mines and coal mines, fasten together at one end three pieces of rubber cord of equal length, whose strengths were proportional to the rate of freight per mile of the quantity of material equivalent to a ton of finished product, and attach the free ends to the corresponding pegs; the junction point would be the equilibrium point and would indicate the proper location of the plant. The strength of the forces acting is profoundly affected by the means of transportation available (whether water or rail) and the location of the equilibrium point is obviously influenced to correspond. The sum of the tensions in all three strings measures the disadvantage under which the district must labor.

"We can see this law demonstrated in the growth of our iron-producing centers. At the time of the Civil War, Pittsburgh was nearly the center of population of the country, and it made, for the next twenty years, the vast bulk of the steel produced, although there was a considerable center in eastern Pennsylvania and New Jersey, in which the fuel, the ore and the consuming population, were all close together and the sum of the tensions was small, so it prospered.

"As the West became settled, the center of population traveled West, first to Ohio, then to Indiana, and then to Illinois, where it is now; simultaneously the Chicago district developed as an iron center although its freight on ore is but little less than to Cleveland and Buffalo while its freight on coal is very much higher; but it is the center of a great consuming district, and its freight on finished product is low enough to make the sum of the string tensions small.

"Later still, Colorado became an iron-producing center, in spite of many disadvantages, because of its location near the center of a consuming district which is far removed from any other source of supply. The sum of its string tensions was high but that of any other iron-producing district is higher in its territory.

"The present construction of a steel plant in Duluth is a further example: The freight on both coal and ore assembled there has been very low for many years; but until the population of the Northwest became large enough to support railroads whose tonnage of steel consumption runs into six or seven figures, it did not pay to build a steel plant there. The freight on the finished product to points of consumption would have been too high.

"At Birmingham the conditions are similar but more marked. The ore and coal are in closer proximity than anywhere else in the known world, the tension in these two strings is almost nothing but the freight to outside consuming centers was so great as more than to counter-balance this advantage; the tension in the single string was more than that of all three at other iron-producing centers and the district made much pig iron but very little money until a local consuming center was built up.

"In the future, the attraction of the center of population will be increased even over what it is now; because the gas, which is a by-product in the production of coke, is of vast value for public heating and lighting and the power which can be produced with surplus gas from the furnace will be increasingly valuable for public utility purposes.

"These products are consumed in steel mills in greater quantity than they are produced by its coke ovens and furnaces, so such works are not to be considered as sources of supply for these products and their location will not be so strongly affected; but the merchant furnace will have gas and power for sale and will more and more be so located that it can dispose of them to good advantage without building long pipe or transmission lines; that is, near centers of population.

"That is, in the future, as we grow more efficient there should be an intimate connection between the iron blast-furnace plant and the public utility, and especially the public utility serving large centers of population."

Careful consideration of the history of the iron business in relation to its location will show that a plant must be located in harmony with this general law in order to have a chance of ultimate success. The importance of the by-product oven in relation to the location of the iron industry may well be a little more elaborated.

Large communities use gas in great quantities and are destined to use it in still greater ones as better processes make gas cheaper and so increase its great advantages for cooking and heating. Its use will also grow with the development of the mantle-light (Welsbach) with pilot flame control giving the convenience of electricity with a source of light as powerful and much more agreeable to many. The candlepower of gas, so important in the days of the open flame burner, is rapidly vanishing as an important consideration on account of the vastly greater amount of light which may be obtained even with a perfectly non-luminous gas, by means of the incandescent mantle.

The by-product oven yields a large quantity of cheap gas of low illuminating, but high calorific, power even after the recovery of the by-products from it, and on this account it is destined more and more to be the source of domestic gas, and this will mean the production in the vicinity of large communities of large quantities of metallurgical coke which being produced as a by-product, will be available at lower prices than an equal grade would command in that location under different conditions.

Where the community is large enough and is a manufacturing one a market for iron will exist and this will lead to the local production of iron in cases where it would be commercially impossible without these favorable conditions.

Construction

Granting that a suitable location has been chosen the size and construction of the plant next demand careful consideration. The most economical furnace to build and to run on the basis of cost per ton is the large furnace, 22 by 90 ft., if there be a market for its product when run continuously. On the other hand, almost any furnace run continuously makes cheaper iron than one run interruptedly, for the advantage of the large furnace has often been overestimated while the disadvantages of interrupted operation, both technically and commercially can scarcely be overestimated, and it is far better to build a furnace of moderate or even small size and keep it operating continuously, than it is to build a large one and run it intermittently. Some approximate figures of the difference in cost of operation of different sized furnaces will be given later.

When the size of furnace to suit the conditions has been decided many questions as to types of construction remain to be decided, and errors are often made in the decision apparently for lack of a guiding principle.

There is often a disregard of cost. Furnaces are built in the prevailing style whether that style was developed for their conditions or not, and without any regard to whether some simpler or less expensive construction would answer. Gas engines are suggested for isolated furnaces with no market for surplus power. Trestles are built 40 and 50 ft. high and then no use made of the storage capacity so created. Bins are constructed so as to give only half the capacity they might have with the same expense. Elaborate coal and ash handling systems are applied to boilers that should properly be fired with gas 95 per cent of the time.

On the other hand, the directors are frequently "penny-wise and pound-foolish." In one case within my own knowledge they insisted on building a new furnace of scrap plate and using an old mantle and columns which necessitated the use of lines for the furnace absolutely unsuited to the conditions under which it had to work. The total saving as compared with building a furnace of new material suited to its work was $10,000. The furnace never did what it was designed to do by a large percentage; the loss per year, due to bad furnace work, was probably not less than $25,000, and at the end of a few years, due to the combination of rotten material and bad lines, the stack fell down bodily in full operation causing a loss of $40,000 to $60,000. Many other instances might be mentioned, none so bad perhaps as this but equally as stupid.

The simple rule by which the value of any construction may be measured is: Find what interest it will pay, indirectly as well as directly upon the investment. There are plenty of justifiable expenditures on which no direct saving can be shown. For instance, to build a modern hearth jacket with water-cooled staves inside a massive steel shell costs several thousand dollars more than to build one of some other types, and one of the latter might go through a blast without a breakout, in which case the return on the money spent for the better one would be nil. But again with the old type during a blast there might be half a dozen breakouts, each of which might cost as much as the increased cost of the safe construction, with the possibility that the explosions which frequently accompany breakouts might kill one or more men. In such a case it is not only foolish but almost criminal to refuse to make the expenditure which practically makes such things impossible.

In the matter of making expenditures to prevent objectionable occurrences which might shut down the furnace it is necessary to remember that certain charges which in operation we spread over the cost of the iron made, run on just the same when the furnace is shut down for repairs. When there is no iron being made to carry them therefore we can truthfully say, however it may sound, "We lose the labor and overhead on all the iron we don't make."

These charges on a 500-ton furnace run from $1.25 to $1.50 per ton, therefore, a twenty-four hour shut-down on such a furnace means a dead loss, exclusive of profits not made, of $600 to $750. This does not include the coke for banking and restoring the furnace to normal operation, or labor for repairs other than that of the regular crew. On this basis it is obvious that to spend $5,000 to prevent a twenty-four-hour shut-down once a month would be a virtual necessity, whereas to spend the same sum to prevent such a shut-down once a year would be open to discussion.

Sometimes it is necessary to estimate what is the probability that a given mishap will occur and on the basis of that probability figure what expenditure is justified to eliminate the possibility of its occurrence.

When it comes to savings whose value per ton can be definitely estimated we are, of course on much surer ground. We have only to estimate the saving per year and compare the amount with the investment required.

Even here certain precautions are necessary. Such investments are not like the purchase of a bond in which the principal is secure and a low return is acceptable.

It is obvious that the return on such an improvement must not be less than that expected from the plant as a whole and as this is never less than fifteen and should be 20 per cent for so irregular a business, it is a safe rule to consider very thoroughly any proposed improvement which will not pay for itself in five years.

Costs

Before entering upon any further discussion of commercial considerations we must have a measure of commercial results of which the most important part is the cost sheet. Cost sheets for pig iron are very simple and are virtually standard. Like all other industrial cost sheets those of pig iron are made up of three items, raw materials, labor, and overhead, but unlike most other products raw materials are far and away more important than both the others put together, and overhead is larger in good plants than labor.

Owing to the fact that the cost of raw materials is fixed by conditions over which the management has no control and that the quantities of each required per ton of iron is subject only to a very limited control, there has come into use a standard of comparisons for costs which consists of the total cost minus the cost of raw materials. This is known as "net cost above materials." This embraces labor, minor supplies, lubricants, relining fund, renewal fund, insurance, taxes, etc. The whole amount varies from $1.25 per ton for large and well run plants to $2.25 for smaller or poorly run ones.

Labor varies from forty to sixty cents on a large mechanically handled furnace, to $1.50 for small hand-operated furnaces. The relining fund must be such an amount that at the end of the blast it will equal two to three times the cost of brick for a new lining. Twenty cents per ton on a 500-ton furnace for a campaign of two years, or say 700 days, is $70,000, which is about three times the cost of a lining for such a furnace. The renewal and repair fund should equal an amount in fifteen years that will rebuild the plant complete except site, as it will practically all wear out or be replaced in that time, and no profit can be properly shown until this depreciation be provided for.

A typical cost sheet without too much sub-division is shown below in Table I. It will be noted that no interest on the investment is shown. This is probably not correct accounting, but is universal practice in blast furnace costs. The fact should not be forgotten in considering the profit and loss shown by any blast furnace operation.

TABLE I—COST OF PRODUCING PIG IRON DURING FIRST SIX MONTHS OF 1914

Furnace "A"

Items of Cost	Pounds	Rate Per Gross Ton	Cost Per Ton of Pig
Ore	3,791	3.56	6.03
Cinder	453	2.77	0.56
Total ore and cinder	4,244	...	6.59
Scrap used	122	6.00	0.327
Gross metallic mixture	4,366	...	6.917
Total scrap produced	115	6.00	0.308
Net metallic mixture	4,251	...	6.609
Coke (net tons)	2,392	3.10	3.74
Coal	....	...	...
Limestone	1,133	0.80	.405
Total fuel and fluxes	....	...	4.145
Total materials charged	....	...	10.754
General superintendence			.082
Stocking			.067
Charging			.045
Casting			.090
Other Producing Labor			.042
Labor in Repairs and Maintenance			.028
Material in repairs and maintenance			.092
Lubricants			.006
Tools, miscellaneous supplies and expense			.034
Tuyeres, blocks and cooling plates			.010
Refractories			.042
General works expense			.167
Blowing expense			...
Steam cost			.056
Water cost			.067
Electric light and power cost			.008
Yard Switching Expense			.112
Laboratory expense			.023
Stable expense			.008
Shop expense			.042
Casting machine expense			.043
Dry air cost			.052
Reserve for relining			.250
Reserve for contingencies			...
Gas credit			...
Total			11.830
Tons produced			76,432
Daily average production			419
Production since relining			276,739

The Most Economical Size and Rate of Driving for Furnaces

As regards the consumption of ore and stone per ton of iron there is no difference between the smallest and the largest size of furnaces using the same material. In regard to coke it might be thought that the large furnace had the advantage due to less radiation and water cooling in proportion to its output, but as a matter of fact small furnaces working under the same conditions otherwise do as well as large ones and have often done much better. The better control of the charging due to their smaller size seems to offset the advantage of smaller heat losses from the larger ones.

We can therefore consider the cost of different-size furnaces only as affected by labor cost, interest and depreciation charges, and power cost.

It is not possible to obtain sufficient information for an absolutely correct solution of the question, but by the use of certain reasonable assumptions we can make some illuminating comparisons. In regard to labor we know that there is a certain irreducible minimum no matter how small the furnace or the tonnage produced, and that an increased tonnage does not require a proportionately increased amount of labor. For instance, the size of the cast house crew does not increase very much between 200 tons and 500 tons output. On the other hand the labor of unloading raw materials from the cars is practically proportional to the amount of raw material. The engine and boiler house crew is only one man per shift for a 100-ton plant but with water tenders, extra oilers, etc., is two or three men in a plant of 500-ton output.

Generally, we may say that the labor for any output is the irreducible minimum for minimum output and for each increase in output an additional amount which increases at a slower rate than the tonnage.

Virtually the same thing is true as to plant cost and fixed charges thereon.

To build a furnace stack of a certain size and the hoist for it, costs the same irrespective of the tonnage to be produced, while the cost of the stoves for large tonnage is more than for small, but not proportionately more. The cost of bins is, however, nearly proportionate to the tonnage to be handled. The cost of the power plan is left out entirely here, because the charges on it are included in the cost of power.

We have seen in the article on the rate of driving that it is easy to obtain a reasonable approximation to the power required to blow any furnace at a given rate and knowing this we can calculate the cost of the plant very simply at so much per horsepower, or what is simpler still, knowing by the experience of various investigators, C. J. Bacon, H. J. Freyn, etc., what is the cost of power development at furnace plants, including fixed

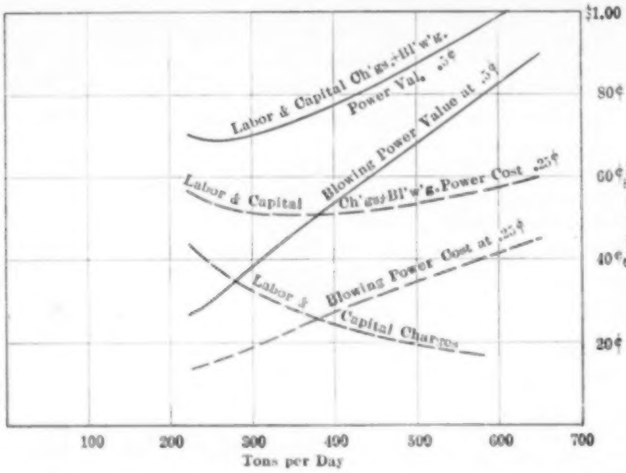


FIG. 1—EFFECT OF INCREASED PRODUCTION ON SUM OF LABOR AND CAPITAL CHARGES + COST OF POWER FOR BLOWING AT. 0.25C. PER HP.-HOUR AND VALUE OF SAME AT 0.50C. FOR 20 X 80 FURNACE

charges, upkeep, labor, lubricants, etc., we can use figures based on their work.

We have, however, two conditions, that where there is a market for surplus power, and that where there is none. In the last case we need consider only what power *costs* without any allowance for the value of the gas, and in the other, what it is *worth* or might reasonably be sold for. I have taken ¼ cent per horsepower hour for the first, and ½ cent for the second, the latter being a very conservative figure.

The value of the three items, labor, fixed charges and blowing cost, in cents per ton on the basis of the assumptions made is shown by Fig. 1 for a furnace 80 x 20. The first two items are of the same character, a fixed amount plus an amount increasing with, but more slowly than the tonnage, and these are therefore added together and their sum per ton of iron shown as one curve, a hyperbola descending to the right. The curves of power cost and power value ascend almost along straight lines to the right. The sum of the former and that one of the two latter which corresponds to the conditions, shows the sum of these costs for these conditions.

These have been calculated for four sizes of furnaces, 17½ ft. x 70 ft., 20 ft. x 80 ft. and 22½ ft. x 90 ft. and 25 ft. x 100 ft., both for power cost and power value.

These are plotted on a common basis of daily tonnage in Fig. 2. The solid lines show power value and the dotted lines show power cost in each case.

Several facts show forth very clearly, first, that each curve has a minimum value or point at which the furnace will produce the cheapest iron on the basis of these costs; second, that the cost of the 17½-ft. x 70-ft. furnace is hopelessly higher than that of the 20-ft. x 80-ft., but that the latter is only a little higher than that of the 22½-ft. x 90-ft., and higher than the 25 x100-ft. by only two or three cents per ton.

In other words, the advantage of large production in lowering cost increases very slowly after the size of furnace reaches 20 x 80 and the tonnage reaches 300, if the cost of the power for blowing be given due weight.

On the other hand, it will be seen that the cost curve of the 22½-ft. x 90-ft. furnace is much flatter than that of the 20-ft. x 80-ft. and that the most economical point can be exceeded considerably with only a slight increase in cost.

The Effect of Rate of Driving on Profits

It seems likely that cost per ton may at times have received too much consideration and profit per day and per year not enough.

It is very true that during several years out of every ten most furnaces have to figure not how much profit they can make, but how small they can keep their losses, for these cannot be cut short by stopping altogether. Fixed charges of interest, taxes, insurance and some salaries run along just the same, and it pays better to run at a loss that does not exceed this amount than to shut down and break up the organization. But at such times we cannot make all the saving represented by the minimum rate over any higher rate because if we are ever to be able to run at a higher rate the investment in power plant for that rate must have been made and the fixed charges on it will go on just the same.

When we come now to the question of profits the question is not one of minimum cost per ton, but of maximum profit per day. As a general thing a furnace is not built unless its projector can see a profit of $1.50 as a minimum for a 500-ton furnace costs with its site and all complete nearly $1,000,000, its output is say, 170,000 tons per year, and $1.50 per ton profit on this is $255,000 per year; capital can be scarcely raised for a smaller return than this in so variable a business.

On the basis of the profit consider the case of the 22½-ft. x 90-ft. furnace on the "power value" basis. The minimum cost for these items is at 300 tons and is 0.65, at 500 tons it is 0.76 or $.11 cents higher. On this basis the $255,000 profit per year on 170,000 tons at $1.50 per ton would become $1.61 per ton, on three-fifths as much 102,000 tons, or $164,220 per year, which would naturally be less acceptable to the owner than $255,000, even though lower costs were made.

It is very obvious from these considerations that 500 tons per day is not the limit of production from the commercial standpoint, and that it is vastly more important to be able to make double the tonnage in good times than it is to make iron for 11 cents less in bad times.

During these relatively rare periods when the profit per ton is several times $1.50 per ton these considerations become correspondingly more powerful and the furnace must be equipped to make a maximum production during these periods even though the fixed charges during hard times are somewhat harder to carry, because in this way we secure the maximum return over a long period.

By-products

There are two important by-products from the blast furnace, the slag and the surplus gas.

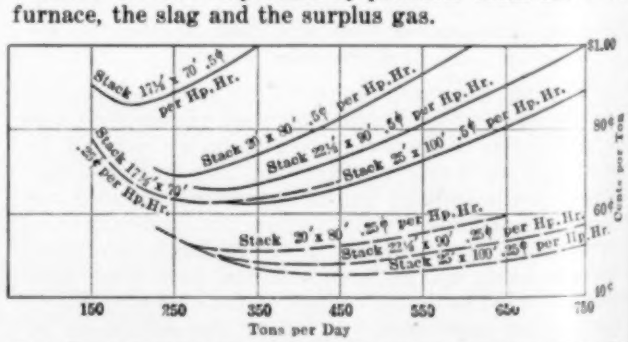


FIG. 2—IRREDUCIBLE LABOR AND BASIC CAPITAL CHARGES PLUS BLOWING POWER REQUIRED AT COST OF PRODUCTION (0.25C.) AND AT SELLING VALUE (0.50C.) PER HORSEPOWER-HOUR FOR FURNACE OF DIFFERENT SIZES AT DIFFERENT RATES OF PRODUCTION

SLAG

This finds utilization in three ways at the present time in this country; others are used in Europe and are under consideration here. First, as a raw material for cement manufacture; second, as aggregates for concrete; third, as filling material. In Europe it is used to make slag building brick and the heat is used to generate steam.

Blast furnace slag consists principally of the three commonest and least valuable of the components of the earth's crust, silica, alumina and lime; any attempt to utilize it, in order to succeeed, must recognize this fact, especially as its composition must be regulated not by the product into which it is to be converted, but principally to suit the conditions of the furnace producing it.

BRICK

The extremely low cost of the natural raw materials for brick manufacture and the high quality of product which can be produced from them has prevented the introduction into the United States of the manufacture on any large scale of slag brick whether cast direct or made by the grinding, mixing and steaming process.

STEAM PRODUCTION FROM SLAG

A plant has been built and operated in England for the production of power from the waste heat of the slag, a project over which many inventors have dreamed.

The development of the low-pressure turbine made the realization of this dream much easier. It seemed only to be necessary to permit the slag to flow into an air-tight chamber containing a good volume of water in the bottom, maintain only enough pressure to exclude the air and utilize the steam formed by the direct action of the slag on the water in a low-pressure turbine.

It was found, however, that the acid vapors generated particularly by the sulphur in the slag ate up the blades of the turbine so rapidly that this plan was out of the question, so a boiler or evaporator was introduced, made of material unaffected by these acids and the original steam was condensed in this with the production of an equivalent amount of pure steam at a somewhat lower pressure. The slag granulated in the first vessel was continuously removed by a bucket elevator working in a sealed compartment.

The success or failure of any such operation depends upon the price of coal in the district and considering the necessarily high plant cost per horsepower of such an installation it seems inherently doubtful whether the value of the equivalent coal saved would pay the high fixed charges. No plant for the generation of power from slag is in use in the United States at this time.

SLAG CEMENT

The slag from a large percentage of the furnaces of the largest iron and steel company in the United States is converted into Portland cement. The slag is granulated by a stream of water as it flows from the furnace, the granulated material is dried, ground, mixed with ground burnt lime in correct proportions, the mixture burnt to clinker in a rotary kiln and the clinker ground to cement. The slag must not contain more than 3 per cent of magnesia in order to make good slag, so the furnaces whose slag is so used are confined to the use of calcite stone. This converts a waste material from a liability to an asset and with the increasing use of concrete the business seems certain to grow, and it is not improbable that better methods of cement manufacture from slag will some day be developed.

SLAG FOR CONCRETE

Slag broken up after being allowed to cool slowly forms excellent aggregates for concrete. Being rough and irregular it produces an excellent bond with the cement, and unlike limestone it does *not* swell and go to pieces under the effect of fire. Its use for this purpose will grow with wider appreciation of its value.

SLAG FILLING

Slag has been used for reclaiming low land, probably from the earliest days of the blast furnace. In those times it was picked up by hand labor and hauled away cold in carts and wagons, but at present it is either flushed to place with the water used to granulate it or taken to the desired location molten in ladle cars.

When filled to a depth of several feet in the latter way it makes a very solid foundation and is much valued on water-front locations, where cheap transportation has caused the location of so many plants in recent years and where there is usually much low land which can be reclaimed by filling.

When a railroad fill or dam is desired, end dump ladles are very desirable as they build an embankment with almost vertical sides and therefore use a minimum of material to which, however, its practically monolithic structure insures great strength.

THE SURPLUS GAS

In earlier articles we have seen that with good power-plant and stove practice about one-half the gas produced by the furnace is available for other purposes after the furnace requirements have been supplied. As the gas contains about half the heat energy of the coke from which it is produced we evidently have available in such a case about 25 per cent of the energy of the coke. This means in the case of a fairly economical 500-ton furnace the heat equivalent of about 100 tons of coal per day. This is evidently an asset of no mean size even where fuel is cheap. How shall we utilize it?

The answer to this question is indissolubly bound up with that of the type of blowing engine to be adopted, already discussed in the article on blowing machinery.

When the furnace is operated in connection with steel works, as about 75 per cent of the furnace capacity is, the steel mill being a heavy consumer of power, the proper and obvious procedure is to convert the heat into power and use it in the steel mill, as is the universal practice in such cases.

The question of the best method to be followed is, however, by no means definitely settled. For those engines in the mill which are steam-driven there is, of course, only one solution, to use the gas for the production of steam, but the power used in mills is increasingly electricity and the question of how best to generate this power is a matter for discussion. The general considerations governing the matter are shown by the following quotations from a lecture before the students of Pennsylvania State College, March, 1915.

The gas engine works on a totally different principle from either the steam engine or the steam turbine and has consequently very different characteristics. It is not capable of much change in speed and its economy drops very rapidly as the load falls off, largely because the friction of the engine is very high and almost constant irrespective of the load, so that a friction of 20 per cent at full load means one of 40 per cent at half load, and so on.

This type of engine is also capable of carrying only very slight overloads, that is to say, its most economical load is its maximum load, and any overload capacity is secured only at the expense of economy and at the price of buying a larger engine. In these respects it is at a great disadvantage as compared with either the steam engine or the turbine, both of which have a large overload capacity which extends far beyond their most economical load.

On the other hand, the gas engine cuts out entirely the boiler, and above all, it has a heat consumption only about two-thirds or three-fourths of that of the best steam plants.

It was at one time supposed that this fact was destined to make the gas engine the preferred prime mover for all electric power work, but other considerations came in and this expectation has not been realized; and some of the best gas-engine men admit that where coal is the fuel used its day of realization has been indefinitely deferred.

Leaving out of consideration altogether the question of first cost and capital charges for the present, let us consider only the operation. Before coal can be used for gas engines, it must be gasified in a gas producer—an apparatus having an efficiency when delivering cold gas (which a gas engine must have) of 75 to 80 per cent, which is almost the same as that of a well-designed and operated boiler plant. So on that basis the two are even. But while coal may be burnt under boilers for a few cents a ton, say 15 cents, in large plants, it cannot be gasified for much less than 45 cents and often 50 cents.

Now the efficiencies of the producer and the boiler being almost the same, the fuel consumed will be in the same ratio as the heat consumption of the two motors themselves, say as a liberal figure 14,000 B.t.u. for the turbine, and 12,300 for the gas engine, a ratio of 1.17 to 1. Then if the coal cost is $1.00 delivered, its cost burned under boilers is $1.15 and gasified $1.45. The fuel cost is proportional, therefore it is $1.15 × 1.17 =$1.34 for the steam turbine and $1.45 for the gas engine. That is, the heat units used by the gas engine are less, but the money cost of fuel is more.

This is all based on full-load conditions, and while the cost for both goes up very rapidly for light loads, owing to the far flatter heat-consumption curve of the turbine and its smaller relative size due to its much greater over-load capacity, its heat consumption rises much more slowly and as the use factor in public service work is about 30 to 40 per cent, it will be perfectly obvious that the advantage of the turbine over the gas engine will be much greater on the average than it is at maximum load, even on the heat-unit basis. Of course, as the cost of coal rises, the case becomes more favorable for the gas engine, at full load, but it is very doubtful if under any ordinary commercial conditions its practical economy on the average is much higher than that of the turbine.

When we come to the iron industry we come to a different condition, very much more favorable to the gas engine. This is that the fuel to be used is already gasified by the blast furnace, this gas being in fact almost an ideal fuel for gas engines, and they are, therefore, entirely freed from any charge or loss of heat for gasification, except that the sensible heat of the gas, 6-8 per cent in good practice, must be sacrificed to fit it for gas-engine use.

The steam plant, on the other hand, is under the necessity of burning this gas under boilers with the same losses as occur in coal firing, excepting that the labor cost is very small. In the past, the economy of furnace boilers has been extremely poor. I have tested boilers on which it was down to 30 per cent. Fifty per cent was about average practice until quite recently, but just at the present time this subject is receiving great attention and boilers are being operated at an efficiency of 75 to 80 per cent in regular operation. In this case the full-load fuel consumptions are proportional to $0.77/1.17 = 0.66$ and $(1.00\text{-}0.07) = 0.93$, or 1.41 to 1, with the further advantage that the gas engine is enabled to dispense with one whole operation and its attendant bother, the gasification of the coal. Moreover, the gas engine has in this service a further great advantage. The use factor is about 60 per cent for electric service in the steel industry, while for blowing engines it is near 80 per cent. Why then are these engines not in universal use in such plants? Here we come to the real milk of the cocoanut.

We have hitherto said nothing of comparative labor costs and of capital charges. In regard to the former the gas engine has had a bad name. The stresses which it undergoes are tremendous, and breakdowns in the past were frequent and serious, while the uncertainty of the engine's going at all was a decided factor in its early days. But if you remember the prayerful uncertainty with which a man started out on an automobile trip ten or twelve years ago, not knowing when or how he would return, and consider our present entire disregard of this as an important factor, you will admit that many of the defects of that type of motor have been removed and that its reliability now fairly challenges that of the steam engine, a condition which is rapidly becoming, if it has not already become, true of the larger types which we are considering. Nevertheless, the number of parts and variety of their movements is vastly greater in this engine than in the turbine and the cost of supervision and operation is correspondingly greater; but leaving this question for a few minutes let us turn to that of capital charges.

These are made up of straight interest and an additional percentage on the investment which is set aside and saved at compound interest, so that at the end of the reasonable life of the plant we may have a sum in the bank equal to the original investment with which we can either pay off the investor or buy a new plant. Any operation which figures its costs on any other basis will probably go broke and certainly ought to. Five per cent at compound interest will equal the principal in about fourteen years, which is about all the life we have a right to expect from a power plant, for if it is not worn out in that time it has most likely been designed off the map. In other words, later improvements will have then made it commercially undesirable to operate any longer, even though it be not nearly worn out.

This 5 per cent added to the 7 per cent interest rate, which must be figured on industrial plants, gives us 12 per cent capital charges over and above all operating costs of every kind. This is a minimum figure for plants of this kind. Make no mistake; these are not bookkeeping figures, and the shores of commercial history are covered with the wrecks of plants which failed to provide for these charges. No sensible business man will put money into a property which cannot figure on this basis and still show a profit.

We see, then, that the annual cost of power is made up of fuel, labor, and one-eighth of the cost of the plant. Let me illustrate this to you. I know of a plant where a furnace is blown with two gas-blowing engines which cost about $100,000 apiece, and which with foundation, house, crane and gas-cleaning apparatus and connections erected complete did not cost less than $275,000. They develop together about 2500 hp., or a cost of $110 per horsepower installed. Coal of 14,000 B.t.u. in this region costs about $1 at the plant.

Steam engines of the best type, with their boilers and all accessories complete could have been installed for $55 per horsepower. These engines would have been required certainly not to exceed 18,000 B.t.u. per horsepower-hour delivered to the boiler, while the gas engine may get along on 12,000. Counting 8780 hours per year, the loss of thermal units per year is 6000 ×

8780 = 52,600,000 B.t.u. That is a large number of heat units. But how much money does it represent? One ton of coal costs fired say $1.15 and contains 2240 × 14,000 = 31,000,000 B.t.u. In other words, it would require 1 2/3 tons of coal per horsepower a year to make up the steam plant's deficiencies, or say, $2 worth.

The difference in fixed charges, on the other hand, is 12 per cent of (110-55) = $6.60 or a net loss of $4.60 per horsepower year by the use of the gas engine with 100 per cent use factor. On the other hand, gas blowing engines are now being built which can be installed for $75 per horsepower, and if these were used in a region where coal cost $2.50 per ton, the cost of make-up coal would be $4.20 and the fixed charges on increased investment be 0.12 × (75-55) = $2.40, a difference of $1.80 in favor of the gas engine under these conditions. This is a little less than 10 per cent on the additional capital required for the gas engine and might be considered a paying though by no means a startling investment, because owing to the uncertainties of industrial earnings, investors are not commonly interested in them unless they can see a manufacturing profit of about 15 per cent; and it is obvious that any additional expenditure required should show this amount or over to be justified. In this case the amount is 7 per cent interest plus 9 per cent net saving or 16 per cent in all. It is right in this range of conditions that it begins to be good business to install gas-blowing engines, though some authorities would insist that at least 2 to 3 per cent larger capital charges should be assessed against the gas engine on account of its high rate of physical depreciation, and all the evidence I have indicates that this is correct.

Turning now to the generation of electric power, we find the conditions different again because we have on the steam side the turbine with the direct rotary movement and its great capacity, while on the other we have the relatively slow speed of the gas engine and the consequent high cost of its generator with probably greater friction and less efficiency than when connected to a blower.

For these conditions we may take costs of $70 and $50 respectively per kilowatt installed and heat consumptions respectively of 12,500 ÷ 94 = 13,300 B.t.u. per horsepower for the gas engine, and

$$\frac{12{,}500 \times 0.96}{0.77} = 15{,}600$$

per horsepower for the turbine, or 17,700 and 21,750 per kilowatt-hour respectively. The use factor is much lower in electric service than it is in blowing-engine service. If we take 60 per cent we shall be liberal. This means that on account of peak loads for which it is necessary to provide, the plant in the course of a year will only put out 60 per cent of its maximum rated power. This factor varies very much in different works, but is higher in all of them than in public service plants.

The heat consumptions are about what may be expected under such conditions of loading and are not altered by this condition and neither are the costs, but the relative relations of these two are profoundly altered.

The excess thermal units per kilowatt year at full-rated capacity for the turbine above those for the gas engine are 8780 × (21,750 — 17,300) = 39,100,000, and the coal to supply this at 31,000,000 B.t.u. per ton is 1.26 tons at $2.50 per ton. This is worth $3.15, but the use factor is only 60 per cent, so that only 60 per cent as much coal is required for make-up, and its value drops to $1.90 while the fixed charges are 12 (70 — 50) = $2.40.

In other words, in such a case the saving in coal would not pay all the capital charges in the increased investment which therefore would be a bad one. Moreover, while the cost of labor and supervision for gas blowers may be no greater than that for steam engines and boilers together, undoubtedly their cost for gas-driven generators is greater than it is for steam turbines and boilers, and this increased cost would further throw the scale against the gas engine. But as the cost of coal rises, conditions are reached under which the gas engine pays, while as its first cost falls the fixed charges fall also, and tend to make its employment sound from the business point of view.

It will now be seen, I think why John Doe in Tyrone, where coal is cheap, may be a fool to do what had paid Richard Roe well in Boston where coal is dear, and the engine that is the most economical of coal may be a lot the most wasteful of dollars.

There are certain electrical considerations involved in the very variable load of the steel mill that give the turbo-generator advantages not covered by this discussion, but of great importance and very tangible value in operation. These considerations probably make it desirable, if not essential, that part of the electric power at least be developed by turbo-generators even if the main supply be from gas engines.

One fact cannot be too strongly emphasized. This is that the decision that a certain type of mover is the best for blowing purposes by no means involves the conclusion that the same type is best for electric power developments. One principal reason for this is that the blowing power for each furnace necessarily being isolated, the largest blowing unit is limited at the most to about 2500 hp., that being the approximate power required to blow a 500-ton furnace, and for safety it is desirable to have this divided into two units, whereas electric units may be built as large as 35,000 hp., and these larger ones are lower in both first and operating cost than the smaller ones, while they are entirely free from the electrical troubles due to variation in angular velocity to which the gas engine is liable.

The greater reliability and smaller upkeep of the turbine give it an advantage over the gas engine not fully covered even by the necessary allowance in operating costs, because certainty of operation has a cash value from the point of view of the whole works which power cost does not touch.

For the generation of electric power the reciprocating steam engine on account of high first cost of generator and higher operating cost is not to be compared with the turbine in powers larger than 2000 hp.

One factor of great importance in decision as between gas and steam engines is that of the efficiency with which the gas is burned under the boilers, while the efficiency of combustion in stoves has an enormous effect on the quantity of gas used for that purpose or left for outside utilization. For many years gas was burnt most wastefully as no attention was paid to the subject, but in recent years it has been carefully investigated and vastly improved. Diehl, Eldridge, Bradford, Boynton, Green, Huessner and a host of others have investigated existing burners and built better ones until the efficiency of boilers using furnace gas has gone from about 50 per cent to over 70 per cent in many cases and nearly 80 per cent in some. With this has gone an increase in the steam produced per boiler which, of course, cuts down the capital cost as well as the fuel cost.

The result is that while the steam motor might have been at a hopeless disadvantage even in spite of its advantage in fixed and operating costs a few years ago, it might easily beat the gas engine on the same basis to-day. The general principles on which these improvements have been made are simple, being merely the

well-known principles of all good combustion, first, correct proportioning of gas and air on the injector principle so that a change in the rate of flow of one makes a corresponding change in the flow of the other; second, the thorough mixing of the air and gas before they reach the zone of combustion; third, the control of the draft at the outlet to the stock so as to maintain the rate of flow of the products of combustion at the best velocity without drawing in any excess air.

The establishment of these conditions may require that either the air or gas be put under light pressure by a fan to supply the velocity required for injector action and for proper mixing, also in some cases to give sufficient velocity without excessive stack draft. The expense of operating the fan is insignificant in comparison with the enormous saving made by the improvement in combustion when these principles are correctly applied.

Where a furnace is not operated in conjunction with steel works there may still be a market for the surplus gas. This may be developed in the form of a sale of electric power to the public service company, but the stringent requirements of continuity in that service have made many operators chary of contracting with them.

Where the gas cannot be sold in this way it may be sold for heating purposes, but the field is rather limited, because the small heat value of the gas makes its transportation expensive and unfits it for any but relatively low temperature operations since the combustion temperature of furnace gas is not high.

In spite of these difficulties the enormous potential value of the gas justifies far greater efforts to conserve and sell its energy than have been made in the past.

In conclusion it is worth repeating that the possibility of disposing of this asset either as electric energy or heat is much greater in the vicinity of a city, and this is destined to induce the location of merchant furnace plants near thickly settled communities in the future to a greater extent than in the past.

Commercial Limitations to Fuel Economy

A few years ago the maximum degree of fuel economy was not only technically desirable, but was commercially necessary for survival, but this is no longer the case. There are conditions in which the commercial results are better with very moderate fuel economy than with the highest. The two developments which have brought about this change are the introduction of the by-product oven and the economic development of power generation with furnace gas, especially the gas engine.

One of the fundamental conditions for the occurrence of this paradox is that there shall be a market for all the surplus power developed. Let us assume then, the most common case of a combined plant of blast furnaces and steel works in which the latter furnish a market for all the power which can be supplied by the former. Assuming a high cost of coal brings out the facts more clearly, let us then assume that coking coal costs $2.10 delivered at the works. If this were coked in old-fashioned ovens the yield would be about 60 per cent and the coking cost would be about 60 cents per ton of coke; coke, therefore, would cost $2.10 \div 0.6 + 0.60 = \$4.10$ per ton, and this cost would represent less than 60 per cent of the heat value of the fuel. The same coke in modern by-product ovens would yield 70 per cent of good screened coke, and the coking cost would be about 75 cents per ton of coke, so that coke would cost $\frac{2.10}{0.7} + 0.75 = 3.75$ per ton. There are, however, some important deductions from this figure. The gas can be sold to the steel works for heating furnaces, the tar and ammonia are recovered (the latter in the form of ammonium sulphate) and sold; while under present and probably future conditions the benzol can be recovered at a handsome profit also.

The value of these by-products varies wth the location, but is seldom or never less than $1 per ton of coal. In a region of high-priced fuel such as we have assumed, $1.50 per ton of coke would be a safe estimate. This would reduce the cost of coke to $2.25 per ton; in other words under such circumstances a ton of coke would cost little more than a ton of coal in spite of the loss of weight and the cost of the operation.

Cases exist in which the coke actually costs less per ton than the coal from which it is made, the value of the by-products making up all the losses and paying all the costs of the operation.

Turning now to the utilization of the coke, all the heat energy it contains, not consumed in the necessary operations of the blast furnace, is returned in in the form of gas, and because this gas contains only a small percentage of its heat in sensible form the efficiency of conversion is very high. Ordinarily the sensible heat of the gas is less than 5 per cent of the heat of the coke, and we may say that the efficiency of the blast furnace in its double function of iron maker and gas producer is 95 per cent; or, on a more conservative basis, we can say that since only about 10 per cent of the total energy of the gas is sensible heat the efficiency of the blast furnace as a gas producer alone is 90 per cent or better, whereas that of the standard gas producer, measured on the basis of the energy in the cold gas divided by that in the coal, is only about 65 to 75 per cent.

We have already seen that the gas engine has a considerable advantage over the steam turbine in heat consumption, if we start with gaseous fuel; and the tremendous efficiency of the blast furnace as a gas producer enables us to utilize this advantage of the gas engine in regions of high-priced fuel where the saving will pay the fixed charges on the greater investment.

In other words, admitting as we must, that there are considerable technical advantages in the use of gaseous fuel for power development, it is obvious that these may be commercially realized much more easily when the gasification is done as it is in the blast furnace with a thermal efficiency of 90 per cent and without labor and capital charges than they can when the efficiency of gasification is 65 per cent and the cost 50 cents per ton of fuel, as in the gas producer.

If we convert as much of the coal into coke as the furnace can conveniently take and utilize the resulting gas to the full, the total fuel and power bill measured in dollars and including fixed charges of a combined plant under such conditions is smaller than if we work with the highest fuel economy in the furnace and supplement the power required by the use of coal either in gas producers or under boilers. Of course, the ability of the furnace to consume coke is limited and its output of iron increases, other things being equal, as the coke per ton of iron decreases, and if we tried to run the coke per ton of iron unreasonably high the iron output would fall and profits be seriously reduced.

It is worthy of note that the highest fuel economy can only be obtained with very high blast heats, which means a decided increase in the gas required for blast heating. After we have reached the limit of commercial coke economy every such increase in gas consumption for this purpose represents an absolute loss.

It is worthy of note also that these conditions bring about a justification for high solution loss, since we

have seen that solution cools down the top gases and reduces the loss due to sensible heat, and it reduces the quantity of blast required per pound of coke and thereby reduces the pressure required to blow the furnace so that there is a material saving in the power consumed per ton of iron, for blowing.

It cannot, however, be too strongly emphasized that where these conditions do not prevail, where the cost per thermal unit of coke is materially higher than that of coal, or where there is no market for all the power which can be produced, or the cost of coal is too low to justify the completest utilization of gas, fuel economy is just as important as it ever was. These are the conditions which generally prevail at merchant furnaces, especially those which buy their coke.

The Dry Blast

The fact that the large steel works of the country have generally not installed dry blast plants has led some of those interested in such matters to believe that there was no ground for the claims of fuel economy made for dry blast, but nothing could be further from the facts. The real case of the dry blast depends upon the considerations set forth in the last section. Where it does not pay commercially to run the furnace for maximum economy for reasons there set forth, obviously it may not pay to install dry blast to obtain fuel economy; but, on the other hand, in the many cases where every pound of coke burnt unnecessarily means so much money lost, especially where the climate is damp, the dry blast is commonly a highly profitable investment.

There are special conditions in which furnaces have available more blast heat than they need or can use, and in such cases the only gain from the dry blast is the increased uniformity of operation, and it is a matter for careful consideration whether dry blast will pay or not.

The most marked instance of this kind is the charcoal furnace with high-blast heat and on rich ores. In the case cited in the article on thermal principles the "hooding in" of the air cylinder of the blowing engine resulted in lowering the moisture very decidedly, but did not have any effect on the fuel economy, and the application of the dry blast to another charcoal furnace running under similar conditions did not have any adequate result on the fuel consumption.

On the other hand, practically all the tests made at merchant coke furnaces equipped with dry-blast plants have shown a saving in coke and an increase in product of a value to pay for the dry-blast plant in two or three years.

It is very unfortunate that dry-blast plants have hitherto not been built in the South where the humidity is high, with the exception of one plant which has not been operated long enough at this writing to demonstrate the advantages of the process in that region. But I have taken records for years at a time which showed a fuel consumption lower by 20 per cent in the dry than in the humid season, and this represented only a part of the total saving. For during the humid season the margin of hearth heat was reduced to the point where slight variations were liable to throw the furnace completely off its balance, and the hearth heat per pound of fuel being very small the furnace was not sensitive to changes of burden and, therefore, very difficult to keep in regular operation. Serious troubles such as breakouts were very much more common, and as a result the operating costs were very much higher during the humid season.

This was so serious that as long ago as 1896 I endeavored to induce the owners to install refrigerating apparatus to dry the blast, and was able to show to my own complete satisfaction that it would have been a vastly profitable investment, but no attention was paid to the suggestion by the owners. This was eight years before the publication of Mr. Gayley's results, and none of us had the slightest idea that anyone else was working on the plan, though I subsequently found that Mr. Gayley had taken out patents on the process two years before I started on it.

On another occasion in the Birmingham district, furnaces running on foundry iron fell off in the grades produced in the early spring, a time when ordinarily the humidity is quite low, but the season had been a very warm one, and when I consulted the humidity records I was astonished to find that the humidity had risen enough to account for the increased coke required to restore the grades, a very considerable amount.

Two points in connection with dry blast are of much importance; first, it is the absolute and not the relative humidity on which the possible saving depends; second, the amount of saving possible is susceptible of reasonably accurate calculations. The relative humidity means the percentage of the moisture which the air actually contains measured in terms of the amount it would contain if saturated *at that temperature*. But the amount of moisture which the air contains at saturation increases with great rapidity as the temperature rises.

Referring to the chart given in the chapter on dry blast, it will be seen that at 0 deg. Fahr. this amount is 0.05 lb. per thousand cubic feet; at 32 deg. Fahr., 0.27 lb.; at 60 deg. Fahr., 0.8 lb.; at 70 deg. Fahr., 1.13 lb., and at 80 deg. Fahr., 1.6 lb; therefore the humidity in percentage means nothing whatever unless we know the temperature. On a foggy day with the temperature at 32 the humidity seems excessive, and in fact fog means that the air is super-saturated; while on a summer day with the thermometer at 80 and the humidity 50 per cent of saturation the air would seem excessively dry, but in the latter case it would contain nearly three times as much moisture per cubic foot as in the former.

We can determine the fuel saving possible in any given case where the humidity during each month of the year is known by the use of the charts of hearth heat in the article on thermal principles. We first determine the average absolute moisture in the air for each month, then decide on the point to which it will pay to dry it, and deduct the coke consumption for the second case from that of the first. To do this, of course, requires a knowledge of the blast and critical temperatures, at least approximately, for the given conditions.

The humidity in the air for each month can be obtained from the nearest Weather Bureau Station. It is desirable to obtain it for at least two years and average the results. This information (furnished freely by the Weather Bureau officials) forms an excellent basis on which to start, but it is necessary to have in mind that these stations are generally located at the highest point available and that the humidity at the ground level may be locally very much higher, especially on the banks of large bodies of water, rivers, lakes or cooling ponds, where furnaces are usually located. Cooling ponds and rivers in industrial districts in particular are likely to throw off large volumes of moisture, even beyond the saturation point of the surrounding air. Within a few hundred yards this is all absorbed and averaged up in the vast volumes of surrounding dry air, so the results at the Weather Station may not be much affected, but the local increase in humidity in the vicinity of the plant may be commercially of great importance.

For the reason it is well to determine definitely the humidity in the vicinity of the blowing engine intake over a period of several weeks at least, and compare the results with those of the Weather Bureau. A few weeks will generally give a fair idea of the local increase, but of course it is desirable to have it for a year if possible.

Knowing the coke saving per ton, and the cost of coke, and the tonnage made per day, we can easily figure the saving from this source. A comparison of this with the cost of a dry-blast plant will generally show that at merchant furnaces without a market for their surplus power the saving will pay for the installation in a short time.

In addition to the saving in fuel and the corresponding increase in tonnage which results, there is a saving in smoothing out the irregularities which result from variations in humidity, whose effect as explained above may be very serious from a financial point of view. This saving, due to the uniformity, has sometimes been claimed to be greater than that due to the drying itself, and while I cannot subscribe to that view there is no doubt that it is extremely important, especially in the case of merchant furnaces where the control of grades is so much more important commercially than at steel works' furnaces.

We can then summarize the status of the dry blast as follows: If first there is a market for heat in the form of combustible gas at a price per thermal unit equal to or better than that for coal, and second, if the money cost of a thermal unit in the form of coke is but little greater than that in the form of coal, the fuel economy in the furnace beyond a point soon reached has a negative value and a dry-blast plant to promote fuel economy, accordingly cannot ordinarily pay. Or where the furnace has available from hot blast alone more hearth heat than it needs for its conditions (practically, this means only charcoal practice on rich ores), the advantage of the dry blast becomes a very secondary one. But where coke consumption reduced means money saved, and where strict grade control means more money earned, then the dry-blast plant is usually a highly profitable investment.

In conclusion it may be pointed out that the introduction of the by-product oven by reducing the value of coke in comparison to that of the coal from which it is made, and the gas engine by giving to the surplus gas from the furnace a commercial value per thermal unit, in some cases equal to that of the coke itself, have been the principal causes of the non-introduction of dry-blast plants at steel works' furnaces.

Annealing of Aluminium*

BY RICHARD SELIGMAN AND PERCY WILLIAMS

It has been shown by various workers that hard worked amorphous metals undergo changes at comparatively low temperatures. Thus Beilby[1] points out that a rapid release of strain occurs in hard worked metals at 100 deg. C., while Lowry and Parker[2], when studying the specific gravity of aluminium filings, observed a decrease in the gravity when the filings were heated to 100 deg. C. Recently Brislee has observed changes in various physical properties of aluminium at 100 deg. C.[3]

During the course of a long series of experiments upon the solubility of aluminium in nitric acid it has been noticed incidentally that by heating hard worked metal to 125 deg. C. a definite change in the rate of dissolution is brought about. Hard worked aluminium is more readily soluble in nitric acid than the same metal when annealed. Thus, for instance, a sample of hard worked aluminium which lost 56 mgr. per 100 sq. cm. per twenty-four hours when immersed in 1.42 nitric only lost 39 mgr. when similarly exposed after being annealed at 500 deg. C., a decrease of 30 per cent.

When the hard worked sheet was heated for 10 hours at 125 deg. C., it was found that the rate of dissolution had fallen from 56 to 53 mgr. per 100 sq. cm. per twenty-four hours. This is equivalent to a decrease of 5.3 per cent. Strips heated at 100 deg. C. instead of 125 deg. C. gave similar results, although the reduction of the rate of dissolution was somewhat smaller, namely, about 3 per cent.

It was anticipated that if the heating were prolonged the decrease in the rate of dissolution might be augmented. This was not found to be the case, but, on the contrary, as the heating at 125 deg. C. was prolonged the fall in the rate of dissolution diminished, until samples heated for 80 hours at 125 deg. C. showed the same or even a slightly higher rate of dissolution than samples which had not been heated at all. This reversal was not noted in the case of samples heated at 100 deg. C., but was observed in a large number of samples heated at 125 deg. C.

The facts recited do not appear to tally completely with the observations of other workers. A release of strain as indicated by Beilby should be accompanied by a reduction in the rate of dissolution, but such a release of strain would not account for the subsequent increase. An allotropic change such as Cohen and others describe for many metals would fit in with the changes in the rate of dissolution observed but for the fact that the reversal took place at the temperature which had brought about the first change. Finally, Brislee appears to differ from all others in that the change he observed went much farther, and seemed to indicate progressive crystallization even at 100 deg. C.

A further anomaly has been observed in dealing with metal annealed at higher temperatures. It has been noted on many occasions that aluminium which has been freshly annealed has a lower rate of dissolution in nitric acid than a sample of the same metal which has been allowed to stand for several days after annealing. Thus, for instance, a sample of metal which, when freshly annealed at 440 deg. C., dissolved in nitric acid at the rate of 31 mgr. per 100 sq. cm. per twenty-four hours, dissolved at the rate of 36 mgr. thirteen days after annealing. On re-annealing at 440 deg. C., the rate of dissolution fell again to 32 mgr. per 100 sq. cm. per twenty-four hours.

Attention is drawn to these facts in the hope that it may be possible for some of those who are interested in these changes to investigate them more closely, as the present authors are not likely to have an opportunity of pursuing the matter farther.

*A paper presented before the Faraday Society in London on May 9, 1910

[1]Beilby, *Trans. Faraday Soc.*, X, p. 212 (1915).

[2]Lowry and Parker. *F. C. S.*, 107, p. 1005 (1905).

[3]Private communication.

Glass-Enameled Steel Apparatus.—The Pfaudler Co., Rochester, N. Y., has issued chemical trades bulletin C-3, describing Pfaudler glass-enameled steel apparatus for chemical industries.

The General Electric Co., Schenectady, N. Y., is planning an interesting exhibit at the Foundry and Machine Exhibition to be held at The Wigmore Coliseum, Cleveland, Ohio, during the week of September 11, in conjunction with the Convention of the American Institute of Metals and the American Foundrymen's Association. The exhibit will include an interesting line of control devices, switchboards, panels, and other material, with a 300-ampere portable arc-welding outfit.

The Time Factor in the Formation of Aromatic Hydrocarbons from a Paraffin Base Oil

BY GUSTAV EGLOFF AND THOMAS J. TWOMEY

The time factor in the thermal decomposition of hydrocarbon oils for the formation of oil gas, gasoline or aromatic compounds of the benzene series is quite as important as the other four variables of chemical reactions: temperature, pressure, concentration and catalysis. In this communication the time factor has been studied in the formation of aromatic hydrocarbons from a paraffin base oil at constant temperature and pressure.

The time factor has been noted by a number of investigators in the thermolizing of a gas oil, for the production of oil gas. Hempel[1] has followed the effect of time upon the composition of oil gas from the cracking of gas oils at temperatures between 700 deg. and 900 deg. C. Tocher[2] and Jones[3] have reported results as to the effect of time upon the products from the heat treatment of oils.

The most systematic piece of work upon the time factor in relationship to the decomposition of a kerosene oil and the resulting products in the gas formed has been made by Whitaker and Alexander.[4] They have shown that the control of the gaseous products formed from the decomposition of a hydrocarbon oil is a function of the time factor when cracking takes place at constant temperature and pressure.

Rittman[5] and co-workers in thermolizing an Oklahoma crude petroleum oil for the production of benzene and toluene at constant temperature, pressure and rates of oil flow from 11 to 27 gal. per hour, found that as the oil rate increased decrease of decomposition of the starting oil occurred. No marked percentage change in the starting oil took place as the rate was increased. A change of only 8 per cent is recorded. This was explained upon the basis of insufficient condensation of the system. Nevertheless, the data as expressed in Table 2 are good qualitative information as to the effect of time upon aromatic formation from a petroleum crude oil. Table 1 gives the analysis of the starting oil, using a Hempel distillation set[6]

TABLE 1

Spec. Grav. 0.817/15.5°c.

Distillation Analysis of Oklahoma Crude Petroleum Used

Temp., Deg. C.	Per Cent Volume	Sp. Gr.
0 to 75	1.5	0.720
75 to 100	3.5	0.722
100 to 125	7.0	0.735
125 to 150	11.0	0.752
150 to 200	14.0	0.782
200 to 250		0.786
250 to 300	15.[illegible]	0.836

TABLE 2

The Formation of Benzene and Toluene from the Cracking of an Oklahoma Crude Petroleum at a Temperature of 700 Deg. C. and 250 Lbs. Pressure at Rates from Eleven to Twenty-seven Gallons Per Hour

Rate, Gals. Per Hr.	Per Cent Recov. Oil	Per Cent Benzene in Recov. Oil	Per Cent Toluene in Recov. Oil	Per Cent Benzene in Orig. Oil	Per Cent Toluene in Orig. Oil
11	21	18.7	13.8	3.9	2.9
14	25	23.2	12.0	5.8	3.0
18	22	20.0	12.7	4.4	2.8
24	25	10.8	10.0	2.7	2.5
27	29	...	...	1.5	2.2

The Time Factor Involved in the Thermal and Pressure Decomposition of a Paraffin Base Oil

The fundamental law of chemical kinetics is expressed in the law of mass action. According to this statement the total progress of a chemical reaction which occurs in a homogeneous system is determined by the difference of the two reaction velocities of the system going in opposite directions as expressed by a reaction equation. From this the velocity of a reaction at every instant of time, *i. e.* the amount of material changed per unit time, may be expressed in the following manner:

The representation of any chemical equation may be expressed:

$$n_1A_1 + n_2A_2 + \ldots . \rightleftarrows n'_1A'_1 + n'_2A'_2 + \ldots .$$

This reciprocal reaction, each of which has a separate reaction velocity and, expressed symbolically, gives:

$$v = k(A_1)^{n1}(A_2)^{n2} \ldots . \quad v' = k'(A'_1)^{n'_1}(A'_2)^{n'_2} \ldots .$$

The change per increment of time $\frac{dx}{dt}$ is shown as follows:

$$\frac{dx}{dt} = v - v' = k(A_1)^{n_1}(A_2)^{n_2} \ldots . - k'(A'_1)^{n'_1}(A'_2)^{n'_2}$$

k' and k are speed constants of the two opposing reactions, A_1A_2 .... are the concentrations of the reacting substances, n_1, n_2 .... are the coefficients of the reacting substances derived from a balanced reaction equation.

Though the above relationships have been studied for reactions of uni, di, tri and higher molecular reactions in which the time factor has been followed, no such relatively simple conditions in a thermolized oil subjected to varying rates of oil flow exists. The cracked oil is an enormously complex mixture of aliphatic and aromatic hydrocarbons and at present the quantitative application of the mass action law is of small value in a study of the temperature, pressure, and time factor involved in the cracking of hydrocarbon oils for aromatic formation.

TABLE 3

Rate, Gals. Per Hour	One Gallon of Oil Vaporized in the Cracking Area in Minutes and Seconds
12	5.00
16	3.45
23	2.36
30	2.00
36	1.39

In this study the effect of rate of oil flow upon the products produced from the reaction at constant temperature and pressure has been made. When the oil is passed into the cracking area, at rates from 12 to 36 gal. per hour, the rates may be expressed in the time factor units as given in Table 3.

The experimental values from Table 5, of 12 gal. per hour, which in point of time gives 5 minutes per gallon of oil in the vapor state, gave maximum decomposition of the starting oil. As the time decreases in which 1 gal. of vaporized oil is in the heated area of the tube, the amount of initial oil decreases. Now in chemical reactions, the time factor which is representative of the interval of time during which a reaction progresses, as illustrated by the above equations, is theoretically deducible from reaction velocity considerations. As shown from the data, increase of rate of oil flow decreases the time in which the oil vapors are in the reaction zone of the heated tube.

Analysis of the Oil Used

The paraffin base oil utilized in these experiments was one which is commonly called a distillate or gas oil. It was derived from a paraffin base Pennsylvania crude petroleum and analyzed as follows: It boiled between the ranges of 200 deg. and 350 deg. C. to the extent of 95.3 per cent. Distillation of the oil was de-

[1]Hempel, Jour. Gasbel. 53, 77, 101, 137, 155. 1910.
[2]Tocher, Jour. Soc. Chem. Ind. 13, 231, 1894.
[3]Jones, Amer. Gaslight Jour. 99, 273, 1913.
[4]Whitaker and Alexander, Jour. Ind. and Eng. Chem. 7, 484, 1913.
[5]U. S. Bureau of Mines Bull. 114.
[6]Rittman, Twomey and Egloff, Met. and Chem. Eng. 13, 682, 1915.

termined by means of a standard 100 c.c. Engler flask. The specific gravity was taken by means of a Westphal balance at 15.5 deg. C. and gave a value of 0.827.

TABLE 4

Temperature, Deg. C.	Per Cent by Volume	Specific Gravity
0 to 200	2.9	....
200 to 250	10.0	0.772
250 to 300	48.6	0.829
300 to 350	33.8	0.855
Residue	4.2	....
Loss	0.5	....

Twenty gallons of oil were used in each experiment.

Experimental Procedure

The paraffin base oil was pumped through a carefully calibrated oil meter at rates from 12 to 36 gal. per hour, at constant temperature of 700 deg. C. and pressure of 150 lb. per sq. in.

The system which was a closed one consisted essentially of a lap welded steel tube of 5/8 in. wall, 11½ ft. in length and 8 in. in diameter. The steel tube was connected with a tar body and stirring rod device for the removal of any carbon formed upon the inner wall of the tube. From the fan box above the tar body a 3-in. header ran to the condensing system which was adequate for these experiments. A triplex pump with an accumulator for the pumping of the oil against the 150-lb. of gas pressure of the system was efficient. A gas-heated muffle-type furnace was used.

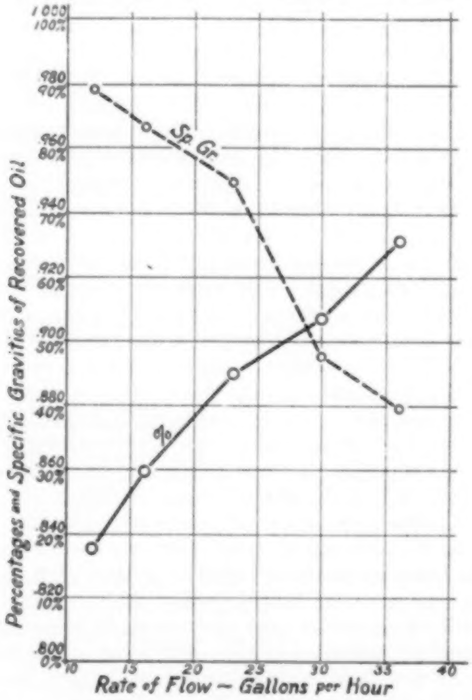


FIG. 1—THE EFFECT OF RATE OF OIL FLOW ON THE PER CENT OF RECOVERED OIL—AND THE SPECIFIC GRAVITY OF THE RECOVERED OIL

Before each run the pressure was built up by means of a compressor to 150 lb. with natural gas. The temperature control was determined by means of a base metal thermo-couple which was accurate to 5 deg. C. plus or minus.

The rate of oil flow into the cracking area under constant temperature and pressure was: 12, 16, 23, 30 and 36 gal. per hour. Before each run the oil meter was carefully calibrated, due to difficulty in finding an oil meter which would remain accurate for any length of time.

By careful regulation of the pressure in the cracking system, the rate of oil flow was maintained constant by the pump. The excess pressure built up by the cracking of the oil was released by means of a pressure valve and was never allowed to exceed or fall below 150 lb. pressure; for change in pressure exerts a marked influence upon the decomposition of the starting oil. The temperature, pressure and rate of oil flow during each experiment were held constant.

Experimental Data

The data as experimentally determined are brought out by means of the following tables and figures:

Table 5 and Fig. 1 give the effect of rate of oil flow on the per cent. of recovered oil and the specific gravity of the recovered oil.

Table 6 and Fig. 2 give the effect of rate of oil flow on the formation of benzene, toluene and xylene in the recovered oil.

Table 7 and Fig. 3 give the effect of rate of oil flow on the formation of benzene, toluene and xylene on the basis of oil used.

Table 8 and Fig 4 give the effect of rate of oil flow on the distillate to 170 deg. C. and the specific gravity of the distillate.

Table 9 and Fig. 5 give the effect of rate of oil flow on the specific gravity of the benzene cut 0 deg. to 95 deg. C.; on the specific gravity of the toluene cut 95 deg. to 120 deg. C.; and the xylene cut 120 deg. to 150 deg. C.

Table 10 and Fig. 6 give the effect of rate of oil flow on the distillation cuts of the oil residue above 170 deg. C. and the specific gravity of the cuts.

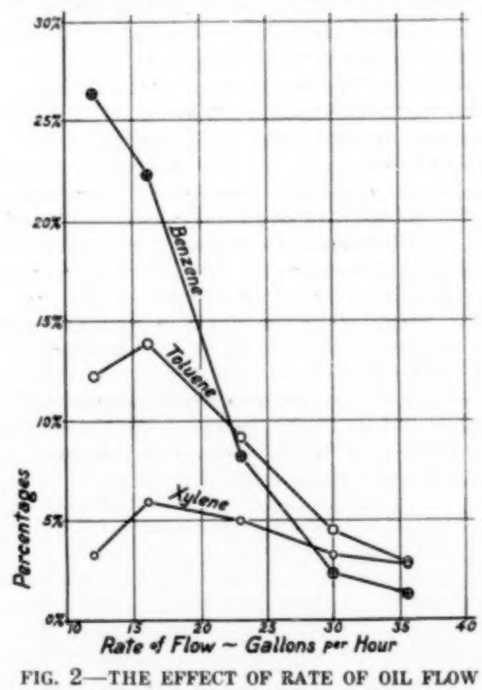


FIG. 2—THE EFFECT OF RATE OF OIL FLOW ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE IN THE RECOVERED OIL

TABLE 5

The Effect of Rate of Oil Flow on the Per Cent of Recovered Oil and the Specific Gravity of the Recovered Oil

Rate Gallons Per Hour	Per Cent of Recovered Oil	Specific Gravity 15.5° C.
12	17.5	0.978
16	29.7	0.966
23	44.8	0.949
30	53.3	0.895
36	65.5	0.879

TABLE 6

The Effect of Rate of Oil Flow on the Formation of Benzene, Toluene and Xylene in the Recovered Oil

Rate Gallons Per Hour	Per Cent Benzene	Per Cent Toluene	Per Cent Xylene
12	26.3	12.3	3.3
16	22.3	13.8	5.9
23	8.3	9.2	4.9
30	2.3	4.5	3.2
36	1.3	2.8	2.7

TABLE 7

The Effect of Rate of Oil Flow on the Formation of Benzene, Toluene and Xylene on the Basis of the Oil Used

Rate Gallons Per Hour	Per Cent Benzene	Per Cent Toluene	Per Cent Xylene
12	4.6	2.2	0.6
16	6.6	4.1	1.8
23	3.7	4.1	2.4
30	1.2	2.4	1.7
36	0.8	1.8	1.7

TABLE 8

The Effect of Rate of Oil Flow on the Distillate to 170° C. and the Specific Gravity of the Distillate

Rate Gallons Per Hour	Per Cent to 170° C.	Specific Gravity 15.5° C.
12	44.3	0.875
16	44.7	0.868
23	35.3	0.837
30	30.9	0.792
36	25.7	0.781

TABLE 9

The Effect of Rate of Oil Flow on the Specific Gravity of the Benzene, Toluene and Xylene Cuts at 15.5° C. / 15.5° C.

Rate Gallons Per Hour	Benzene Cut 0° to 95° C.	Toluene Cut 95° to 120° C.	Xylene Cut 120° to 150° C.
12	0.876	0.872	0.871
16	0.868	0.867	0.869
23	0.814	0.848	0.852
30	0.756	0.815	0.823
26	0.744	0.800	0.814

TABLE 10

The Effect of Rate of Oil Flow on the Distillation Cuts of the Oil Above 170° C. and the Specific Gravity of the Cuts

Rate, Gallons	170° to 230° C.		230° to 270° C.		270° to Tar		Tar
Per Hr.	Per Cent	Sp.Gr.	Per Cent	Sp.Gr.	Per Cent	Sp.Gr.	Per Cent
12	18.0	solid	28.6	solid	8.5	solid	44.6
16	13.0	"	29.4	"	16.0	"	41.6
23	12.1	0.923	35.7	0.954	12.7	0.995	39.6
30	15.7	0.891	27.6	0.905	24.2	0.930	32.8
36	21.4	0.884	30.0	0.902	21.0	0.911	27.6

Discussion of Experimental Data

A.—THE EFFECT OF RATE OF OIL FLOW ON THE PER CENT OF RECOVERED OIL AND THE SPECIFIC GRAVITY OF THE RECOVERED OIL

When a paraffin base oil is passed through a heated tube above the vaporization point of the hydrocarbons present, dependent upon the temperature of decomposition[7] profound changes take place in the starting oil.

The oil recovered from the cracking is composed of aliphatic and aromatic hydrocarbons differing in their constitution as the temperature is increased.

Likewise the time factor or the rate of oil flow into the heated area of the tube brings about profound changes in the initial oil. By varying the time factor at constant temperature and pressure, the recovered oil differed in constitution from the starting oil and from each other widely.

From Fig. 1 it will be observed that the rate of oil flow has a marked effect upon the per cent of recovered oil obtained in each experiment.

A priori reasoning would indicate that the amount of decomposition of the oil should be directly proportional to the time factor or rate of oil flow. Quite different results were obtained experimentally.

The maximum decomposition took place between 12 and 16 gal. per hour, where for each gallon change in rate a difference of 3.05 per cent in the recovered oil resulted. From 16 to 23 gal. per hour a change of 2.16 per cent took place per gallon change in rate. The minimum of change took place between the rates 23 and 30 of 1.2 per cent. As the rate was increased from 30 to 36 the change per gallon of oil flow gave a 2.05 per cent difference in the recovered oil.

This indicates the close inter-relationship of the temperature and the time factor, for in a previous set of experiments where the temperature effect was studied, a critical temperature drop was noted quite similar in its characteristics, to the time factor.[8] The per cent of recovered oil increased as the rate of oil flow was increased, while the per cent of recovered oil decreased with increase of temperature.

The specific gravity changed from 0.827 in the initial oil to 0.978 in the recovered oil as the rate of oil flow decreased from 36 to 12 gal. per hour.

With increase of temperature the specific gravity[8] of the recovered oil increased also. This is in accord with the increase of specific gravity with increase of the time factor.

Due to the time factor at constant temperature of 700 deg. C. and 150 lb. pressure, the initial oil had changed from a paraffin oil to a mixture of paraffin, ethylene and perhaps acetylene series, and, aromatic hydrocarbons of the benzene and polycyclic seried hydrocarbons.

From the high specific gravity of 0.978 in the 12 gal. per hour experiment, the lowest oil flow, the maximum aromatic formation is indicated.[9]

B.—THE EFFECT OF RATE OF OIL FLOW ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE IN THE RECOVERED OIL

The effect of rate of oil flow upon the formation of benzene, toluene and xylene in the recovered oil is brought out by the data and Fig. 2. The interesting fact to be noted in the graph is that as the initial oil in the vapor state is allowed to remain in the heated zone the least in point of time or the maximum rate of 36 gal. per hour, the toluene and xylene form in greater quantity than benzene. This is equivalent to cracking at low temperature.[10]

As the time factor is increased benzene forms more rapidly than either toluene or xylene and at the maximum time of 5 minutes per gallon of vaporized oil in the heated zone, benzene formed is over twice the per cent of toluene and over seven times that of xylene.

The per cent of benzene decreased with increase of rate of oil flow from 12 to 16 gal. per hour, with a steep drop from 16 to 23, less so from 23 to 30 and only slightly from 30 to 36.

The changes in the formation of toluene are less marked and almost a constant increment of per cent of toluene is to be noted between the rates 16 to 30 gal. per hour. A slight falling off of toluene was found to occur at the rate of 12 gal. per hour. This would indicate that the toluene decomposed more rapidly to form benzene.[11] The maximum formation of 13.8 per cent of toluene occurred at rate of oil flow of 16 gal. per hour.

The formation of xylene is much less than either toluene or benzene with one exception, at 36 gal. per hour. This rate gave the least decomposition of the starting oil. The maximum formation of 5.9 per cent of xylene occurred at 16 gal. per hour.

The conclusion drawn from these data is that as the initial oil vapors are allowed to remain in the cracking zone increasing lengths of time, the formation of xylene and toluene decrease and benzene increases to the maximum. The maximum of benzene was found to be 26.3 per cent at twelve gal. per hour, while the maximum for toluene was 13.8 and 5.9 per cent for xylene both at the rate of 16 gal. per hour. This brings out the control possible for the maximum formation of the hydrocarbon desired in the recovered oil by change of the time factor.

C.—THE EFFECT OF RATE OF OIL FLOW ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE ON THE BASIS OF OIL USED

Industrially the important fact is the production of maximum per cents of the most valuable aromatic hy-

[7]Egloff and Twomey, Jour. Phys. Chem., 20, 121, 1916.

[8]Ibid.

[9]Rittman and Egloff, Jour. Ind. Eng. Chem. 7, 481. 1915.

[10]Egloff and Twomey, Jour. Phys. Chem. 20, 121, 1916.

[11]Rittman, Byron and Egloff, Jour. Ind. Eng. Chem. 7, 1019. 1915.

drocarbons, benzene, toluene and xylene on the basis of oil used for their production.

In the graph resulting on the basis of oil used two factors are considered, the per cent of aromatic compound in the recovered oil and the per cent of the recovered oil.

In contradistinction to the curves for the aromatic compounds in the recovered oil the curves on the basis of oil used for benzene, toluene and xylene all show a

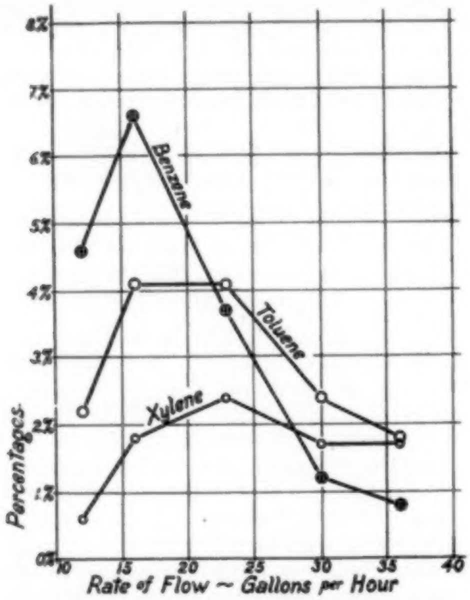


FIG. 3—THE EFFECT OF RATE OF OIL FLOW ON THE FORMATION OF BENZENE, TOLUENE AND XYLENE ON THE BASIS OF THE OIL USED

maximum but not under the same time factor or rate of oil flow.

The difference between the two sets of graphs lies in the fact that as the time factor increases, the percentage of aromatic formation increases while the per cent of recovered oil decreases.

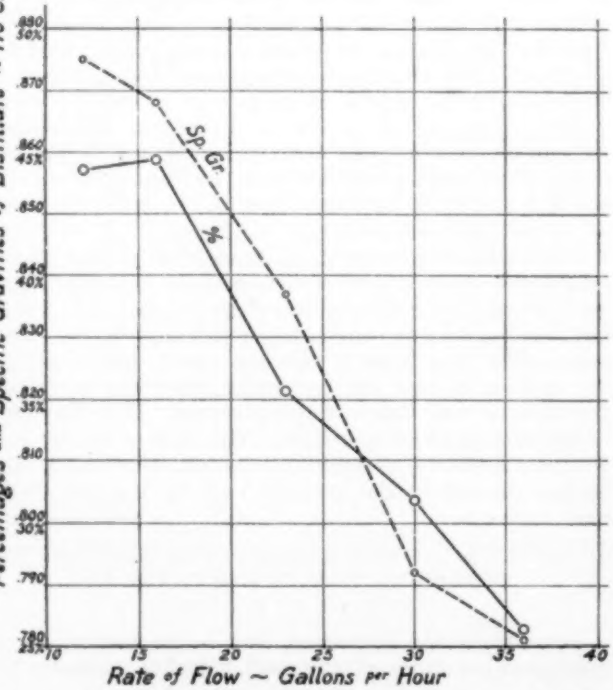


FIG. 4—THE EFFECT OF RATE OF OIL FLOW ON THE DISTILLATE TO 170° C. AND THE SPECIFIC GRAVITY OF THE DISTILLATE

Up to a certain point illustrated in the rate of oil flow for the different maxima shown, the per cent of the aromatic formation increased more rapidly than the per cent of the recovered oil decreased. With this factor influencing more than the latter, the per cent of the aromatic compounds on the basis of the oil used increased.

As the rate is further decreased the decomposition of the initial oil progresses more rapidly than the formation of the aromatics. A combination of these two factors brings about a maximum in the curve for aromatic formation.

In the recovered oil the formation of benzene, toluene, and xylene show different velocities of formation, with increase of the time factor. The maximum for benzene of 6.6 per cent on the basis of oil used was at the rate of 16 gal. per hour, or 3′ 45″ per gallon of oil vaporized in the heated zone. For toluene the maximum of 4.1 per cent was at the rate of oil flow of 16 and 23 gal. per hour, or expressed as actual time 3′ 45″ and 2′ 36″ per gal. of oil vaporized. Xylene gave a maximum of 2.4 per cent at 23 gal. per hour or 2′ 36″ per gal. of oil in the vapor state.

The graph is valuable in indicating the best conditions of oil rate at constant condition of temperature

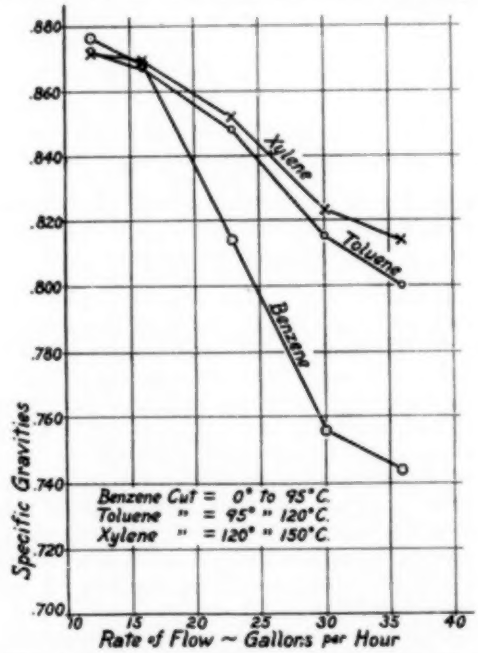


FIG. 5—THE EFFECT OF RATE OF OIL FLOW ON THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS AT 15.5° C.—15.5° C.

700 deg. C. and 150 lb. pressure, for the formation of the aromatic hydrocarbons, benzene, toluene and xylene.

D.—THE EFFECT OF RATE OF OIL FLOW ON THE DISTILLATE TO 170 DEG. C. AND THE SPECIFIC GRAVITY OF THE DISTILLATE

The effect of rate of oil flow upon the distillate to 170 deg. C. is shown in Fig. 4 and indicates that as the time factor increases the percentage increases to a maximum and then decreases. The maximum formation of distillate to 170 deg. C. occurred at 16 gal. per hour and least at 36. The falling off at 12 gal. per hour is readily explainable upon the basis of an increased formation of polycyclic aromatic compounds which have higher boiling points than the derivatives of the benzene series.

The specific gravity of the distillate increases with increase of the time factor to the maximum of 0.875

which is clear indication that the distillate is composed practically of pure aromatic hydrocarbons.[12] At the lower specific gravities mixtures of paraffins, olefins and aromatic hydrocarbons are present, while increase of specific gravity indicates increase of aromatic compounds.

E.—THE EFFECT OF RATE OF OIL FLOW ON THE SPECIFIC GRAVITY OF THE BENZENE, TOLUENE AND XYLENE CUTS AT 15.5 DEG./15.5 DEG. C.

As the time factor increases from 2 to 5 minutes in which 1 gal. of oil in the vapor state is subjected to the heated zone of the tube, the purity of the cuts of benzene, toluene, and xylene increases until at the longest period of time, 12 gal. per hour of oil flow, almost pure benzene, toluene and xylene results from the cracking conditions of the experiment.

A specific gravity of 0.876 for benzene, 0.872 for toluene and 0.871 for the xylene cuts gives practically pure compounds which are readily separated by fractional distillation and clean up readily upon treatment with concentrated sulphuric acid.

In the other cuts with lower specific gravities a mixture of low boiling aliphatic hydrocarbons of the paraffin and olefin type are present, mixed with the aromatic hydrocarbons, benzene, toluene and xylene. The low boiling aliphatic hydrocarbons can readily be used for motor fuel either alone or blending with uncracked gasoline.

An idea of the purity of the distillation cuts from the specific gravity[13] values, a comparison of the average gravity of the aliphatic hydrocarbons which have boiling points around those of benzene, toluene and xylene are given the following table:

	Average Spec. Grav. Aliphatic Compounds	Spec. Grav. Aromatics
Benzene cut 0° to 95° C.	0.72	0.881
Toluene cut 95° to 120° C.	0.73	0.871
Xylene cut 120° to 150° C.	0.76	0.869

The data indicate the changes produced upon increasing the time factor and that as the time of reaction is increased benzene, toluene and xylene relatively free from the aliphatic hydrocarbons of the paraffin and olefin type are formed.

F.—THE EFFECT OF RATE OF OIL FLOW UPON THE DISTILLATE FROM THE RECOVERED OIL ABOVE 170 DEG. C. AS SHOWN BY DISTILLATION CUTS AND SPECIFIC GRAVITY

As the time factor increased the recovered oil was mainly aromatic in character.

At 12 and 16 gal. per hour the cuts from 170 deg. C. to tar gave naphthalene and anthracene, as shown by their appearance as solids in the cuts.

As the time of reaction decreased the polycyclic aromatic compounds decreased to zero.

It is of interest to note that as the time factor decreased the formation of tar or pitch decreased in the distillate above 170 deg. C. The mixture above 170 deg. C. is an extremely complex system and no regularity appears to be present judging from Fig. 6.

A minimum occurs in the cut from 170 deg. C. to 270 deg. C. Two maxima appear in the cut from 230 deg. C. to 270 deg. C., while the same appears to be true of the cut to tar.

The per cent of tar decreased with increase of rate of oil flow.

SUMMARY

1. The effect of the time factor or rate of oil flow has been studied at a constant temperature of 700 deg. C. and 150 lb. pressure and rates of 12, 16, 23, 30 and 36 gal. per hour, for the formation of the aromatic hydrocarbons benzene, toluene and xylene from a paraffin base oil.

2. (*a*) As the time factor increased the per cent of recovered oil decreased from 65.5 to 17.5 per cent. The time factor is analogous to the effect of increasing the temperature of decomposition of the starting oil.

(*b*) Increase of the time factor increases the specific gravity of the recovered oil from 0.879 to 0.978/15.5 deg. C. The same phenomenon takes place when the temperature of thermolization of an oil is increased.

3. The maximum per cent of 26.3 of benzene in the recovered oil was found to be at the rate of 12 gal. per hour. The benzene formation increased with decrease

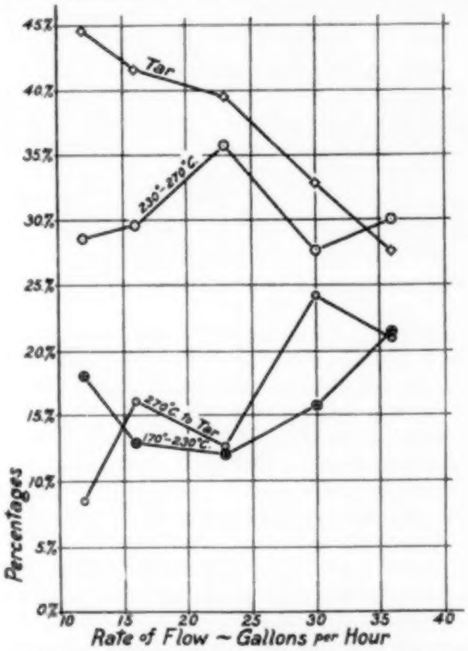


FIG. 6—THE EFFECT OF RATE OF OIL FLOW ON THE DISTILLATION CUTS 170°—230° C., 230°—270° C., 270° TO TAR, AND TAR

of rate of oil flow. The maximum percentages of 13.8 per cent toluene and 5.9 per cent of xylene were both obtained at the rate of 16 gal. per hour. Toluene and xylene showed an increase and then decrease, in their formation, while benzene increased continuously with increase of the time factor within the range of these experiments.

4. The maximum 6.6 per cent of benzene on the basis of oil used was obtained at 12 gal. per hour. The maximum for toluene of 4.1 was found at rates of oil flow 16 and 23 gal. per hour. Maximum formation of xylene of 2.4 per cent at 23 gal. per hour resulted at the temperature of the experiments 700 deg. C. and 150 lb. per square inch.

5. The per cent of distillate increased with increase of the time factor to a maximum of 44.7 per cent and then decreased. The specific gravity of the distillate to 170 deg. C. increased to 0.875 which indicated practically pure aromatic compounds of benzene, toluene and xylene present. The lower specific gravity of the distillate gave mixtures of aliphatic and aromatic hydrocarbons.

6. The specific gravity of the benzene, toluene and xylene cuts indicated the varying amounts of mixtures of paraffins, ethylene and aromatic series of hydrocarbons present. **At the rate of 12 gal. per hour maximum purity of the cuts was obtained. Practically pure benzene, toluene and xylene were obtained from a paraffin base oil under these conditions of the experiment.**

[12] Rittman, Twomey and Egloff, Met. and Chem. Eng. 13, 682, 1915.
[13] Rittman, Twomey and Egloff, Met. and Chem. Eng. 13, 682, 1915.

7. No regularity is apparent in the distillation cuts above 170 deg. C. with exception of the tar or pitch formation. Pitch formation decreased with increase of rate of oil flow.

8. Under the conditions of the experiments a maximum total of 12.5 gal. of the aromatic compounds benzene, toluene and xylene were obtained from 100 gal. of oil used, at rate of 16 gal. per hour, temperature of 700 deg. C. and 150 lb. pressure per square inch.

Department of Chemistry,
Columbia University, New York City.

Notes from the Palmer Physical Laboratory

Maximum Watt-Dissipation is Still Air from Nickel Wire and Other Data

BY E. S. NORTHRUP

In the tests to be described the objects held in view were: a—To determine the watts per cm² dissipated in still air from the surface of pure nickel wires with circular cross-section when raised by the passage through them of the electric current to their melting temperature and to observe how this quantity depends upon the diameter of the wire.

b—To find the per cent elongation of a nickel wire when raised from room temperature to its melting temperature.

c—To ascertain the carrying capacity in amperes of nickel wires of different diameters when raised by the passage of the current to the melting point, the wires being in still air and lying horizontal.

d—To find the resistivity of pure nickel when at a temperature just below melting.

For obtaining the above information from a single experiment the device and electrical circuits shown in Fig. 1 were devised.

The wire to be tested was stretched between two binding posts pp'. These posts were mounted on a board B covered on the top side with asbestos sheet for protection against burning. A spring S was hooked to the wire at its middle point, which would raise it up when it increased in length on heating by an amount h. The height h by which the spring raises the wire was measured with a steel scale. Then from a knowledge of the length l and the height h the length l_1 is easily calculated and consequently the percentage increase in length may be at once determined from the relation $\frac{l_1 - l}{l} 100 =$ per cent increase in length. Provision for heating the wire till it reached its melting point and broke was made by passing through it alternating current derived from a transformer with voltage tap-off points, the current being further regulated with a control rheostat. A wattmeter was introduced in the icrcuit and also an ammeter in the manner clearly shown in the figure.

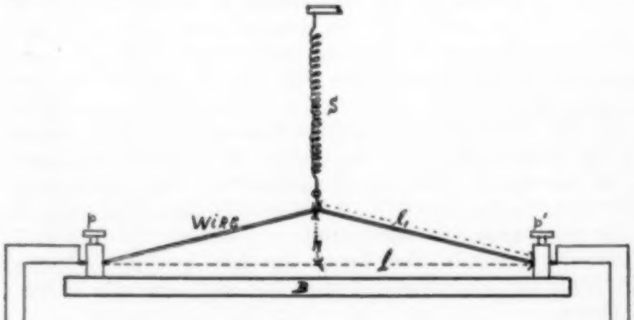


FIG. 1—EXPERIMENTAL ARRANGEMENT

Since the melting point of pure nickel is accurately known, namely, 1452 deg. C., it is evident that if the current through the wire is slowly increased until the wire melts and the circuit opens, its temperature at this moment must be very approximately the melting temperature of nickel. If furthermore, the length and diameter of the wire is known and the wattmeter and the ammeter are read just before or at the instant that the wire melts and the height h be also measured, all necessary facts are known for calculating; the per cent increase in length of the wire in being raised from room temperature to its melting point, the watts being dissipated per cm² from its surface when at its melting temperature, the maximum number of amperes which it can carry in still air and the resistivity of nickel, just as it reaches its melting point.

The resistivity of the wire is given by the formula

$$P = \frac{\pi r^2}{L} \frac{W}{I^2} = \text{resistivity of nickel at melting temperature.}$$

In this formula r is the radius of the wire obtained with michrometer callipers and L its length. Strictly speaking L should be taken as the length which the wire has attained at the moment of melting, but the error is very slight if the distance between the binding posts pp' is taken as the length of the wire. This distance was in all cases 50 cm. W is the watts read on the wattmeter and I the current read on the ammeter.

In obtaining the data the writer was assisted by several students. He is indebted to Mr. H. F. Porter for working up the data into convenient form for exposition.

Wires of four different sizes were tested and where in the second, seventh and eighth columns of the table of results two figures appear these represent the figures obtained from two independent experiments made on wire of the same size.

All the essential data and results which were obtained are embodied in the table given below.

DATA AND RESULTS
All wires 50 cm. long between binding posts. Ni melts at 1452° C.

Wire Diameter in Cm.	Total Watts Dissipated	Rise of Spring in Cm.	Total Length Increase of Wire in Cm.	Per Cent Increase in Length	Total Superficial Area, Cm.²	Watt per Cm.²	Max. Amps. Carried	Resistivity at Melting Point, Microhms	Times Increase in Resistivity
0.0246	270	6.5	1.6	3.22	4.003	67.5	6.24	64.5	6.7
0.051	475 465	5.8 5.8	1.32	3.22	8.273	56.75 56.22	16.7 16.5		
0.0755	650 640				12.28	52.74 52.12	29.15 28.70		
0.199	3300 3400				102.3	32.26 32.74	63.0 63.3		

Precision attained probably between 1 and 2 per cent.

The following points may be mentioned: The results give the very upper limits of current and watt-carrying capacity of a rheostat constructed in the very common form of winding a wire in a spiral. Possibly nichrome, which is said to melt at a slightly higher temperature than nickel, would carry a little more.

The results give the very maximum of watt-dissipation in still air of straight horizontally stretched nickel wires. In round numbers one may say that 50 watts to the square centimeter of heat dissipating surface is about the ordinary limit of wires having the high melting point of nickel. Of course, if resistance wires are wound on cylinders as in resistance furnaces and packed round with heat insulating material they will dissipate but a small fraction of the watts and carry but a small fraction of the current given in the above table of results which apply only to the condition of

the wire being stretched in a horizontal position in still air.

It is very interesting to note that wires of small diameter can get rid of their heat per square centimeter at about twice the rate that a wire of large diameter can.

The method above described would not be applicable with any degree of precision to wires made of metals which oxidize rapidly, such as copper. However, the oxidation might be prevented by plating wires of a readily oxidizable metal with nickel.

The increase in the resistivity of nickel in passing to the melting point from room temperature is about 6.7 times its resistivity at room temperature. It is highly probable that on melting the resistivity suddenly doubles, though I am not aware that this determination has been made in the case of nickel.

The per cent increase in the length of the wire was 3.22, an amount quite sufficient to cause a nickel wire wound tightly on a cylinder of refractory material to loosen up badly when brought to a high temperature. It is this fact that makes it generally unsatisfactory to endeavor to secure furnace resistance wires firmly on a refractory cylinder by covering them over with a refractory cement. The cement generally scales off, due to the expansion of the wire.

Notes on Copper Smelting at the United Verde Copper Company

(Editorial Correspondence)

The new smelting plant of the United Verde Copper Company, erected in 1914-15, is situated at Clarkdale, Ariz., in the valley of the Verde River, about 5 miles distant and 2000 ft. below the town of Jerome, where the old plant was situated.

The Clarkdale smelter is equipped for both reverberatory and blast-furnace smelting by the most approved modern methods, and although erected primarily to treat the company's own ores, it is available for smelting such custom ores as are offered from the district. Blast-furnace smelting is the more important operation, with regard to tonnage treated, but the reverberatory furnaces are a valuable adjunct for smelting fine ore and flue-dust.

TABLE I—CONSTITUENTS OF BLAST-FURNACE CHARGE

	Iron Ore	Silica Ore	Oxide Ore	Converter Chips	Limestone
Cu per cent	5.5	5.8	0.8	9.5	—
SiO_2 per cent	11.5	22.0	70.0	16.0	6.0
Fe per cent	33.0	26.0	17.0	47.0	—
S per cent	37.0	25.0	1.2	6.5	—
CaO per cent	—	—	—	—	50.0

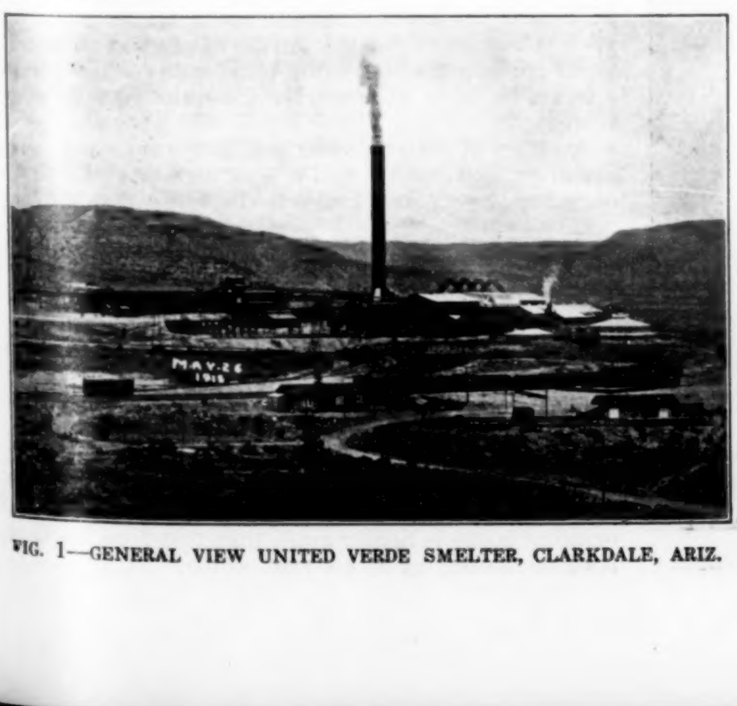


FIG. 1—GENERAL VIEW UNITED VERDE SMELTER, CLARKDALE, ARIZ.

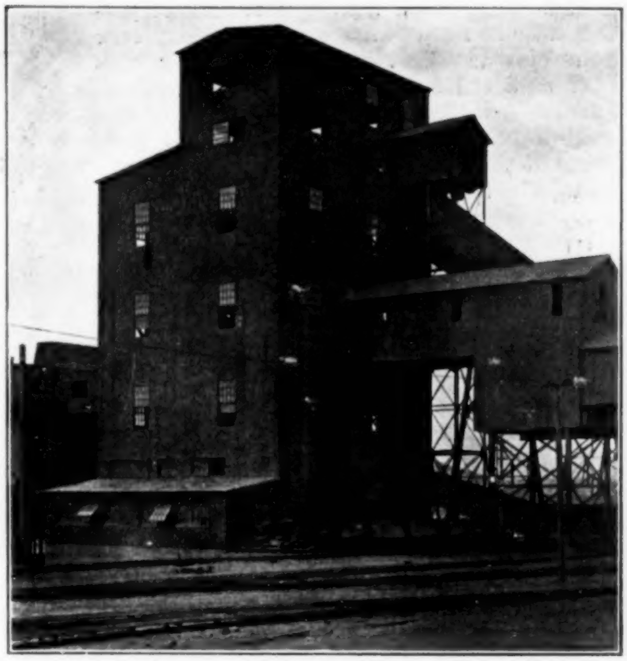


FIG. 2—SAMPLE MILL, UNITED VERDE SMELTER

The company's mine affords three types of ore, making a mixture that is largely self-fluxing, and in addition thereto a high grade of limestone is obtained from a local deposit. Typical analyses of the three classes of ore are given in Table I. The most important is a heavy sulphide, well suited to blast-furnace treatment. The second type is a more silicious sulphide, and the third an oxidized highly silicious ore. At the smelter these ores are designated as iron, silica and oxide respectively. The last is used not only as a constituent of the blast-furnace charge, but portions of it are so highly silicious as to be useful for converter flux and reverberatory fettling. An important characteristic of the United Verde ore is its remarkable freedom from arsenic and antimony.

Blast Furnace Smelting

An uncommon feature of the blast furnaces is the Giroux hot-blast top, in which air is preheated before going to the tuyeres. This was a characteristic of the furnaces at the old plant at Jerome and has been retained. The first cost of construction is, of course, greater than for furnaces with brick superstructure, and additional power is required to force the air through the pipes; but the company's metallurgists are convinced that definite advantages accrue from this construction in the increased temperature of the blast and convenience of operation. The economy and efficiency of hot blast have long been realized in iron smelting, where the inflammable gases evolved from the furnace are used as fuel in preheating air. Since no such gases are evolved in any quantity in copper matting, economy of heat in smelting is sought by preheating the blast in separate U-pipe stoves or in specially constructed furnace tops like the Giroux. The advantages claimed for hot blast are reduction in the percentage of coke required, conservation of heat and acceleration of reaction between the components of the charge. With the Giroux construction the charge may be smelted with hot top without risk of damaging the furnace superstructure.

Table II shows a typical blast-furnace performance on run-of-mine ore for a twenty-four hour period. Blast pressure is 30 oz. The coke used contains 22 per cent ash, and the quantity averages about 6 per cent of the weight of the charge. Copper on the charge is about 5 per cent and sulphur about 25 per cent. The matte will average 23 per cent copper. A typical slag analysis is given in Table III.

Blast-furnace gases are conducted by two flues from each furnace to a dust chamber running parallel with the furnace building. The interior of this chamber is fitted with baffles that give the gases a tortuous path throughout the entire length. The bulk of the dust is recovered here, and the gases continue through a short flue to the 400-ft. brick-lined steel stack. Analysis of the flue dust is given in Table IV.

FIG. 4—CONVERTER ROOM, UNITED VERDE SMELTER

Roasting and Reverberatory Smelting

The roasting plant for fine ore comprises six six-hearth, air-cooled Wedge furnaces, 21 ft. 6 in. in diameter, with rabble arms traveling at the rate of about one revolution in two minutes. Auxiliary oil burners are provided which are portable to the several hearth doors. These are for occasional use when the ore is coarse or low in sulphur, or for any other reason not roasting properly. No limestone is added to the furnace charge. Feed will average 28 per cent sulphur and the calcine 8 to 9 per cent. Under these conditions each furnace shows a capacity of 90 tons in twenty-four hours, and the entire battery is operated by a 30-hp. motor. Flue dust is collected in a chamber fitted with plate and wire baffles.

Reverberatory furnaces are 19 ft. wide by 100 ft. long. One of the three is constructed for charging through hoppers arranged above the side walls. The other two are charged through central hoppers in the usual manner but have side hoppers for fettling material. Each furnace has two 700-hp. Stirling waste-heat boilers which, however, can be oil-fired independently of furnace operation.

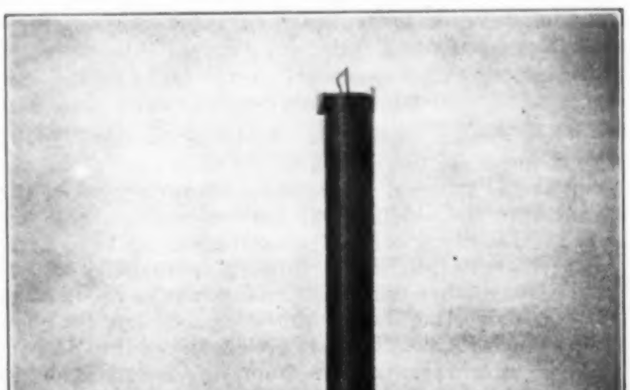


FIG. 3—400-FT. STEEL STACK, UNITED VERDE SMELTER

The furnaces also are oil-fired, using California crude oil under a feed pressure of 60 lb. and at a temperature of 170 deg. Fahr. Air is delivered to the nozzles at 15 lb. pressure. Reverberatory capacity is in excess of present requirements, but on the completion of a proposed crushing and screening plant at the tunnel mouth a larger quantity of fine ore will require reverberatory treatment.

TABLE II—TYPICAL BLAST-FURNACE TONNAGE, 24 HR.

Tons	Material
217	Iron ore
218	Silica ore
30	Oxide ore
18	Limestone
32	Converter cleanings
515	
29.7	Coke = 5.8 per cent of charge

TABLE III—SLAG ANALYSES

	Blast-Furnace	Reverberatory
SiO_2 per cent	39.0	38.0
FeO per cent	43.0	43.0
Al_2O_3 per cent	9.5	12.0
CaO per cent	2.5	0.5
Cu per cent	0.2	0.35

TABLE IV—CONSTITUENTS OF REVERBERATORY CHARGE

	Calcine	Blast-Furnace Flue-Dust	Silica Ore Fettling
Cu per cent	6.5	9.0	4.0
SiO_2 per cent	21.5	24.0	80.0
Fe per cent	32.0	30.0	4.0
S per cent	9.3	14.0	1.5

Analyses of materials charged to the reverberatories are given in Table IV, and a typical reverberatory tonnage for twenty-four hours in Table V. The oil consumed in smelting the 333 tons of charge indicated was 262 bbl., giving a fuel ratio of 0.79 bbl. per ton of solid charge. The quantity of converter slag delivered to the furnace is not recorded, nor are any figures available from which to credit the fuel ratio with heat utilized at the boilers. With this credit applied the fuel consumption would appear much lower. Reverberatory matte is higher grade than that from the blast furnaces, averaging 35 per cent copper.

TABLE V—TYPICAL REVERBERATORY TONNAGE, 24 HR.

Tons	Material
232	Calcine
62	Blast-furnace flue-dust
39	Silica ore fettling

Basic Converting

The converting equipment consists of five stands and eight shells of the Great Falls type, 12 ft. in diameter and lined with magnesite. The output is 80 tons of copper per day. Silicious ore used for converter flux has approximately the same composition as that shown for reverberatory fettling in Table IV. Two tons of ore is used in the converters for every ton of copper produced. Air is supplied at 15 lb. pressure from several blowing units, the latest of which is a turbo-blower running at 2500 r.p.m. and having a capacity of 24,000 cu. ft. of free air per minute.

The blister copper produced at the United Verde smelter is 99.25 per cent pure, and as stated before is remarkably free from arsenic and antimony. It is taken from the converters in 10-ton ladles and cast into 365-lb. bars in two casting machines. Converter slag is charged both to the reverberatory furnaces and blast-furnace settlers.

Earlier mention was made of a proposed crushing and screening plant at the mine. The construction of this plant will benefit both blast-furnace and reverberatory operations. For the former it will insure the delivery of raw ore free from fine material, thereby making for increased tonnage, reduction in flue dust, and possibly a lower consumption of coke. For the reverberatories it will afford a supply of material more nearly equal to the present furnace capacity.

Smelting operations of the United Verde Copper Company are under the direction of Mr. Thomas Taylor, superintendent, and Mr. H. N. Thomson, metallurgist.

Some Technical Applications of Capillary and Electrocapillary Chemistry*

BY W. C. McC. LEWIS, M. A., D. SC.

Capillary chemistry, as the name suggests, deals with phenomena which occur at the surface or interface which separates two phases. The term "surface" or "interface," in this connection, does not refer to the mathematical concept of a surface (which has no physical existence). What is meant is the very thin interfacial layer caused by the interpenetration of both phases, which extends to a very slight depth, not exceeding the effective range of molecular attractions, that is in all probability a few millionths of a centimeter.

It might be thought that effects which are limited to such dimensions would never play any significant rôle in physico-chemical phenomena. This is true up to a certain point. Given the proper conditions, however, surface effects play not only a significant, but even a decisive part in the observed phenomena. The necessary condition is that the surface shall be large compared to the mass or bulk of at least one of the phases. Under this condition it is to be expected that the force known as surface tension may lead to the production of phenomena not observable when the phases which constitute the system are present in bulk.

To illustrate the point, let us consider the phenomenon of adsorption. Suppose we have an aqueous solution of, say, sugar in contact with an oil in which both sugar and water are insoluble; then, if the presence of the sugar modifies the interfacial tension between the oil and the water, it will be found that the concentration of the sugar in the interfacial layer is not identical with its concentration in the bulk of the solution. This surface-concentration effect is denoted by the term adsorption to distinguish it from absorption which means the distribution of the solute throughout the entire bulk of a phase.

*A paper read before the Liverpool Section of the Society of Chemical Industry. From the issue of May 31, 1916, of the *Journal of the Society*.

The phenomenon of adsorption is one of the most important and characteristic features of capillary chemistry. It was first put on a sound theoretical basis by Willard Gibbs, who showed that the phenomenon depended upon the effect produced by the dissolved substance upon the value of the interfacial tension between the two immiscible phases. Gibbs proved by thermodynamic means that if a dissolved substance was capable of lowering the interfacial tension, then the substance would be positively adsorbed at the interface; that is, its concentration in the surface layer would be greater than its average concentration in the bulk of the same phase. On the other hand, if the dissolved substance was capable of raising the interfacial tension it would suffer adsorption at the surface; that is, its surface concentration would be less than its average concentration in the bulk of the phase.

One can test Gibbs' expression by forming an emulsion of, say, hydrocarbon oil in an aqueous solution of some substance which is quite insoluble in the oil in the ordinary sense, but which has the property of lowering the interfacial tension oil-water. It will be found that the concentration of the dissolved substance throughout the bulk of the water is less than its concentration previous to the formation of the large interface produced by emulsifying the oil. That is, some of the substance is now closely adhering to the oil-water interface at a higher concentration than that possessed by it in the bulk of the water. The bulk concentration has consequently been depleted to allow of the adsorption layer being formed. Two conditions are postulated in Gibbs' deduction: first, the phenomenon must be reversible; that is, if the concentration of the solute in the bulk of the aqueous phase be diminished the surface concentration must likewise diminish; and secondly, the bulk concentration must not exceed the limits of applicability of the perfect gas laws.

The reference of the term emulsions suggests two other kinds of systems very similar in nature and behavior, namely, suspensions and colloidal solutions. Suspensions, emulsions, and colloidal solutions are all ultimately governed by the same laws. They are all fine-grained systems, possessing large interfacial area compared to the mass of the disperse phase. Suspensions represent systems having the largest size of particles (diameter approximately 10^{-4} cm.), emulsions come next with diameter of the order 10^{-5} cm., and colloidal solutions represent the highest stage of subdivisions, with particles the diameter of which is usually of the order 10^{-6} cm.

It is an important though not easily understood fact that great variation in size of the particles in one and the same system renders the system an unstable one, with the result that the particles, instead of remaining in permanent distribution throughout the liquid medium, agglomerate or coagulate, giving rise to a jelly-like mass, called a gel to distinguish it from the stable suspended state, which is termed the sol.

Since suspensions, emulsions and colloidal solutions are characterized by the possession of large interfacial area, it is obvious that adsorption effects may take place upon the particles of these systems just as in the case of porous bodies possessing large surface area, such as charcoal, textile fabrics, paper, sand, and soil. Suspensions, emulsions, and colloidal solutions possess, in addition, certain well-marked characteristics more particularly associated with the phenomenon of their stability in the disperse or sol form, and the conditions which determine the conversion of the sol into the gel.

The first point is the determination of the average size of particles in a colloidal solution, or what amounts roughly to the same thing, the apparent molecular

weight of the colloid in the sol form. From the fact that colloid particles are invisible under a high-power microscope, Bredig inferred that the diameter must be less than 10^{-4} cm. From the fact that colloidal solutions possess the property of polarizing light, Lobry de Bruyn concluded that the diameter could not be less than 5 to $10\mu\mu$; that is, of the order 10^{-6} to 10^{-7} cm. Other considerations, also based upon optical effects, have led to the value 5×10^{-6} cm. for the average diameter of colloidal metals. As regards molecular weight, the result of applying the ordinary osmotic expression—which, by the way, seems to be a perfectly justifiable procedure in view of the work of Perrin and others—has led to enormous values: e. g., 5000 for gelatin, 15,000 for albumin in water.

A further point of interest is the so-called Brownian movement, exhibited by suspended particles, and due to the bombardment of the particles by the molecules of the medium. Although this phenomenon is of great theoretical interest, it is not proposed to consider it further in this place, since in the few technical applications of capillary chemistry which it is proposed to deal with later no explicit use of the phenomenon is made.

We may now pass to what is probably the most important phenomenon in connection with colloids, namely, the *electric charge* which the particles possess and the mechanism of *coagulation*, which is intimately connected with the removal of the electric charge. Practically all particles in the stable colloidal or emulsoidal state are electrically charged. In aqueous solution, colloidal metals, sulphides, and oil emulsions are negatively charged, while colloidal hydroxides and many organic substances are positively charged.

The sign of the charge is most conveniently determined by placing the colloidal solution or emulsion in a U-tube fitted with platinum electrodes, and observing the direction of motion of the particles under the applied electromotive force. This movement is termed *cataphoresis*. When the particles arrive at the electrode, which is naturally charged in the opposite sense to that of the particles themselves, the latter are discharged, and coagulate together to form a gelatinous mass at the electrode which is easily distinguishable by the eye.

It is a remarkable fact that the removal of the charge should bring about coagulation. The simplest view of the matter, though probably an inadequate view, is that coagulation is prevented by the electrostatic repulsions of charges of the same sign, and that when the repulsion is removed by the discharge the accidental impacts of the now uncharged particles result in the building up of large aggregates which are precipitated by the action of gravity.

That gravity does not cause the precipitation of individual particles, even apart from their charge, is probably due to the fact of Brownian movement, the particles being retained in suspension in virtue of the bombardments by the molecules of the medium.

A matter of the greatest uncertainty is the problem of the ultimate source of the electric charge, which the particles carry.

We know that colloids can be discharged and coagulated, not only by contact with an oppositely charged electrode, but also by means of electrolytic ions of opposite sign, the coagulating effect of such ions increasing generally with their valency. Thus $Al^{\cdot\cdot\cdot}$ ion, which possesses three positive charges, is a better coagulant of a negatively charged colloid, such as colloidal arsenic sulphide, than is $Ba^{\cdot\cdot}$, which carries two positive charges; and this, in turn, is much more effective than a monovalent ion such as $Na^{\cdot}$.

In view of the fact that ions can bring about discharge, it has been inferred that the charge in the first place was conferred by the adsorption upon the surface of the colloid of one of the ions of the medium, say $H^{\cdot}$ or OH', when water is the medium. Such a view as this receives considerable support from the behavior of a colloid such as albumin, which has been shown by Hardy to be neutral, or nearly so, in pure water, positively charged in acid solution where $H^{\cdot}$ is in excess, and negatively charged in alkaline solution where OH' is in excess. I am inclined to think, however, that albumin is rather a special case. The difficulty of accepting the ionic-charge view as a sufficient one is evident when it is remembered that colloidal solutions may be obtained in media in which it is difficult to believe that ions exist. Thus Billiter has prepared colloidal platinum in chloroform, in which the colloid is electrically charged; and what is equally remarkable, the charge is a positive one, although in water colloidal platinum is negatively charged. Further, the process of spraying liquids through an orifice into a vacuum, or into a gas, confers a charge upon the particles. This process is hardly distinguishable from the more familiar cases of frictional electricity.

In my opinion, the origin of the charge carried by a colloid or emulsion particle is the same as that which we recognize as frictional electricity. In this connection it is very significant that in general the sign of the charge carried by a particle is determined by the relative values of the dielectric constant of the disperse phase and the medium the phase which possesses the higher dielectric constant being the positively charged one. Now, water is a substance with a characteristically high dielectric constant, and it is to be anticipated, therefore, that in the majority of emulsions and colloidal solutions which contain water the water will be positively charged with respect to the particles; or, what is the same thing, the particles will be negatively charged with respect to the medium. Although one can obtain positively charged colloids in water, it can probably be stated that the majority of colloidal solutions in water contain particles which are negatively charged.

It would be rash, however, to believe that dielectric constant is the only determining factor. Even granting the frictional idea, we are still met with the difficulty of visualizing with any degree of clearness the relative distribution of the opposite charges existing respectively on the particle and upon the neighboring molecules of the medium. The usual view is due to Helmholtz, and is, therefore, spoken of as the "Helmholtz double-layer" theory. According to this, a colloid particle and the surrounding layer of molecules of the medium can be regarded as a small condenser with a certain potential difference between the surface of the colloid and the nearest layer of molecules.

But this does not really take us very far unless we postulate something further about this system. It will be observed that a system represented by a charged colloid particle surrounded by a layer of oppositely charged molecules is, strictly speaking, electrically neutral as far as an external field of force is concerned. An effective charge can only be produced in such a system if there is a certain amount of "give" between the nucleus and the outer layer; and the fact that colloids do move in an electric field is evidence that such a "give" takes place.

Lamb (Phil. Mag., 1888) is practically the only investigator who has attempted to deal quantitatively with this point by introducing a factor called the "facility of slip" into his expression for the potential difference across the "double layer."

It is obvious that any attempts to determine the *actual* charge carried by a colloid particle are very liable to

error. What we do measure is the much smaller quantity, namely, the *effective* charge, which is dependent upon the magnitude of the facility of slip. If the facility of slip were zero, that is, if there were no "give" between the layers, the colloid-condenser system would possess no effective charge at all, though the true charge upon the particle might be considerable. The results of such determinations have hitherto been very discordant, and we really do not know with any certainty the true charge on a colloid particle.*

Although this is the case with regard to the charge, the value of the potential difference between the colloid particle and the surrounding medium is much more accurately known. We are particularly indebted to E. F. Burton (Phil. Mag. 1906) for having carried out the first quantitative measurements in this direction. As a rough approximation, one may say that the potential difference amounts to 0.05 volt for practically all colloids and emulsions. The determination of this potential has great significance for the phenomenon of coagulation, for it has been found that by addition of a suitable electrolyte it can be reduced to zero, and may even be carried through zero to real values of opposite sign.

The position at which the potential difference is zero has been called by Hardy the isoelectric point, and it was considered that this corresponded to the optimum condition for coagulation, or what is the same thing, at the isoelectric point the colloid is most unstable. Although this is nearly true, the actual coincidence of iso electric point and maximum instability has been called in question. This problem is, therefore, in a state of considerable uncertainty.

A similarly unsatisfactory state of things exists in relation to the discharging effect produced by ions when we come to examine the phenomenon closely. It is easy to conceive of a positive ion, such as $Al^{\cdots}$ being absorbed upon a negative colloid and discharging it, but what rôle are we to attribute to the negative iron originally associated with the $Al^{\cdots}$ ion? It is known, for example, that aluminum sulphate possesses a different coagulating power from aluminum chloride—but why? We can only say that we do not know. Even the recent work of Bancroft (Trans. Amer. Electrochem. Soc., 1915, 27, 175), which has increased our knowledge of such phenomena very considerably, does not get us further than the conclusion that there is a specific adsorption effect entering in all cases, specific not only with respect to the ions, but likewise with respect to the colloid. It is clear that an immense field lies untouched in such problems as these.

Before passing from the problem of electric charge and coagulation it is necessary to deal very briefly with the closely allied phenomena of *colloid-protective effect* and *peptonization*. It is well known that a colloidal solution of platinum in water can be rendered much more stable by the addition of a small amount of gelatin. The gelatin acts as a preservative. In this case, one colloid stabilizes or protects the other. In the phenomenon of peptonization we have what may be described as the reverse of coagulation. That is, certain gels may be converted into sols by the action of reagents. Thus the gel hydroxides of zinc, aluminum, and chromium can be converted into the sol form by addition of excess of caustic potash. It is to Bancroft (loc. cit) that we owe the idea that protective effect and peptonization are one and the same thing.

To illustrate the point, a sentence or two may be quoted from a recent paper by Bancroft (l. c.) dealing with the behavior of mixtures of chromic and ferric salts with excess of alkali: "Hydrous (hydrated) chromic oxide is peptonized by caustic potash, while hydrous ferric oxide is not. If the chromium salt is present in large amount relatively to the iron salt, the ferric hydroxide will absorb the peptonized chromic hydroxide and be peptonized by it, thereby going apparently into solution. If the ferric salt is present in excess it will absorb the peptonized chromic hydroxide, carrying it out of the liquid phase. It is to be noticed that the chromic hydroxide, when in excess, acts as a so-called protestive colloid to the iron hydroxide."

There still remains one other phenomenon of capillary chemistry, the importance of which is very great, both from the scientific and technical standpoint, namely, the phenomenon of *electro-osmosis*, or *endosmosis*. By electro-osmosis is meant the movement of a liquid through a membrane or through a capillary tube toward one of the electrodes when the membrane or tube is placed in an electric field of force between the two electrodes. The phenomenon is due to the fact that at the glass-liquid interface there is a potential difference, due to charges of opposite sign resident upon the glass, and the neighboring molecules of the liquid. These charges are not rigidly fixed, and can, therefore, slip from one molecule to another, in a sense, parallel to the axis of the tube.

It has long been known that if water be placed in a vessel divided in half by a vertical, porous membrane, and an electrode be placed in each half, then the water will move through the membrane under the influence of the external e.m.f., so that the level rises in one half and falls in the other. This phenomenon is similar to cataphoresis, with this difference: that in cataphoresis the liquid medium remains approximately stationary during the passage of the suspended particles through it, while in electro-osmosis the medium itself moves, the diaphragm being fixed.

From what has been said already regarding the origin and magnitude of the electric charge on colloid particles it is obvious that our knowledge of the phenomenon of electro-osmosis is somewhat unsatisfactory. In this, as in other applications of capillary and electrocapillary chemistry, technical practice is considerably ahead of theory.

Some Applications of Capillary and Electrocapillary Chemistry to Chemical Industry

The following list, which is by no means exhaustive, will serve to illustrate the variety of technical processes in which capillary effects play an important rôle:

Rubber preparation. Vulcanization.
Separation of ore constituents.
Sprayers for crops. Soil fertility.
Rôle of colloidal iron in plant growth.
Medicinal emulsions. Milk. Cream formation.
Beverages. Liquid foods. Enzymes. Inorganic ferments.
Peptonization. Clotting. Physiological fluids.
Emulsions for photographic purposes.
Gums and adhesive materials.
Inks and marking fluids. Pigments.
Dyes and dyeing. Bleaching, tanning, staining.
Paper sizing and coloring. Carbon and other copying papers.
Soap maufacture and cleansing action.
De-emulsification of water in steam turbines.
Filtration processes. Peat drying, etc.
Sewage treatment. River sludge. Charcoal purifiers.
Colloidal metals in fused melts. Ruby glass. Opaque glass. Enamel.
Cement. Mortar. Plaster.

*For a fuller discussion of the problem see the chapter on colloids contained in the author's "System of Physical Chemistry" in Sir William Ramsay's series of text books.

Rôle of colloids in electrolysis.

Contact catalytic processes.

A few of the problems involved in some of the above applications of capillarity will be considered under the following heads: (a) general capillary principles; (b) technincally important emulsions and colloidal solutions; (c) adsorption; (d) coagulation; (e) selective adsorption (of ions); (f) protective effect; (g) electro-osmosis.

(a) Application of General Capillary Principles to Certain Technical Problems

As an example, we may consider the theory of wetting and the *determination of wetting power*. This is of great importance, especially in agricultural practice, since it is a determining factor in the efficiency of liquid sprayers. A special case has recently been examined by Cooper and Nuttall (J. Agric. Science, 1915, 7, 219-230). These investigators point out that the efficiency of a spraying liquid is not solely dependent upon the amount of toxic substance present, the wetting power being of equal importance.

The wetting power depends upon the value of the interfacial tension between two phases, this value determining whether a liquid, A, will wet or run over the surface of a second liquid or solid, B. The value of the interfacial tension can be modified by adsorption phenomena, since positive adsorption necessarily accompanies a decrease in tension. The lower the tension the greater the wetting power.

To get efficient spraying it is, therefore, necessary to have present some substance which markedly lowers the tension. For this purpose, soap, or a substance having a "soap basis," is particularly suitable, and is, therefore, recommended by these authors.

(b) Technically Important Emulsions and Colloidal Solutions

One of the most important emulsions we have already referred to in sprayers, or spraying liquids. These usually consist of an oil of some kind emulsified with water which contains a substance possessing toxic properties, such as basic copper salts, in the case of potato spraying to prevent potato blight. In such cases as these the emulsion which is formed by mechanical means is very far from being uniform, and can scarcely be regarded as stable. In the case of medicinal emulsions, such as cod liver oil emulsion, the preparation is carried out with greater care, a much more uniform and therefore more permanent emulsion resulting. Artificial beverages are, for the most part, emulsions or colloidal solutions. Cocoa and coffee, for example, may be regarded as emulsions, tea as a colloidal solution. The production of tannin-free tea depends upon the fact that the colloidal tannin can be coagulated and separated. As regards natural emulsions, the most important of all is, of course, milk. Milk is only a moderately stable emulsion, and in many respects this is a decided advantage, otherwise cream might have remained an unknown commodity.

Another exceedingly important emulsion which occurs naturally is rubber latex. Reference will be made to this later in dealing with its coagulation.

Besides colloidal solutions in which the liquid medium is usually water or aqueous solutions, there are a number of others which are only liquid in the sense of being mobile at relatively high temperatures. I refer to glasses and enamels. Ruby glass, for example, is a very beautiful illustration of a true colloidal solution of extremely high viscosity, the colloid being a metal, the medium a mixture of fused salts. Many such colloidal solutions have been known for centuries. Among recent preparations of such solutions may be mentioned that of translucent glass. Such substances, however, are of very complex composition, so that while one feels justified in instancing them as examples of the colloidal state it must at the same time be confessed that the knowledge we possess of colloids is far too limited to be of much use in dealing with complex cases and still less with suggesting improvements on rational lines. It would appear that empirical methods must unfortunately be relied on for perhaps a long time yet in such cases, for the lag between theory and practice is unfortunately great.

The question of photographic emulsions will be briefly considered in dealing with electro-osmotic processes.

(c) Technical Applications of Adsorption

Technical processes in which adsorption plays an essential part are very numerous. In the place of first importance one should mention *dyeing* processes. It is now fairly generally recognized that the first stage in such processes is a true adsorptive one. Dyestuffs are generally characterized by exerting a very marked lowering effect upon surface and interfacial tension. It follows therefore from Gibbs' principle that they are largely adsorbed, with the result that in the surface layer (which probably does not xeceed 10^{-6} cm. in thickness) the concentration of the dye becomes great, eventually exceeding the limit of solubility which it possesses in the ordinary sense. The result is that precipitation or coagulation takes place and this in many cases is accompanied or succeeded by ordinary chemical combination with certain of the amphoteric substances present in the material to be dyed.

It is clear, of course, that adsorption cannot cover the whole phenomenon, for adsorption in the sense of Gibbs' theory is a reversible process, while dyeing is essentially an irreversible process, the fastness of the dye being dependent upon the fact of irreversibility.

In the case of *tanning* the process is very similar. A reference will be made to tanning later from the standpoint of electro-osmosis. It will be observed that in dyeing and tanning we are dealing primarily with the adsorption of colloidal matter upon a surface, most dyestuffs such as Congo red belonging to the group of so-called "electrolytic colloids," that is the colloidal part functions as an ion (anion).

Bleaching processes, while being fundamentally adsorptive in nature, differ from the preceding cases in that the bleaching agent is not usually a colloid and therefore its effect upon the surface is a better defined chemical process. A bleaching agent such as sodium hypochlorite lowers the surface tension of water and hence is positively adsorbed at the surface.

Surface-adsorption of molecules and ions of electrolytes plays a fundamental rôle in *agricultural problems*. One of the results so far obtained in this very complex subject is the conclusion that the general character of a soil is as much governed by the size of grain, that is, by the surface area of the soil particles, as by their chemical nature. Heavy clay means small porosity, and therefore small surface and small adsorbing power for salts and non-electrolytes dissolved in the water present. The result is that this material is unsatisfactory. The function of adsorption in soils is to retain the soluble salts from being washed away too far from the surface of the ground during heavy rain. The extent to which adsorption occurs depends not only upon the soil but also upon the nature of the fertilizer. The question of the efficiency of fertilizers would lead us too far, but that the problem is fast becoming an exact applied science is very evident. It is cleár on general grounds that capillary chemistry plays a great rôle in such prob-

lems, as we have already seen in connection with the theory of wetting, but it is to be feared that many of the workers in this field have not fully realized the significance of capillarity for the processes concerned.

A further important technical application of adsorption is found in the methods of *water* and *sewage purification* in so far as *filtration* is concerned. The functions of porous substances such as charcoal and sand are so familiar that they need not be considered at length. It is sufficient to point out that capillary adsorption is the fundamental factor, though, as in dyeing and tanning, the irreversibility of the process is an essential, and in so far as irreversibility exists the phenomenon is not covered by the simple capillary theory. Purification problems also come under the head of coagulation of colloids and a brief reference to them will be made there.

Another field in which adsorption plays a part is that of the *cleansing action of soap* and the *clarification of liquids*, such as wines. In the case of soap there is no doubt that the alkali produced as a result of hydrolysis acts as a peptoniser or emulsifier for the fatty matter which is to be removed, and the intimate contact, which is necessary to attain this, is possibly brought about by the fact that the soap, both unhydrolyzed and as colloid ions, depresses the interfacial tension with the result that adsorption of the soap takes place and capillary wetting occurs easily.

In the case of clarification processes the results of a particular investigation may be cited as illustrative, the object being to find a good clarifying agent for certain wines which would be effective without altering the taste appreciably. According to F. La Marca (see this Journal, 1915, p. 1066), "experiments with nine types of Italian wines indicate that fish glue was the best clarifying agent." The tannin and extract content can be reduced by adsorption upon the fish glue without altering other constituents. "Egg albumen is also an excellent clarifier and does not alter the composition of the wine." Aluminous earth markedly reduces the acid content and also the extract, but not the color or the tannin. "Acidity and color are diminished by charcoal, which also reduces the tannin to a slight extent." The specific effects of adsorption upon surfaces of different nature manifest themselves here very clearly.

(d) Application of Coagulation Principles

Coagulation, as already pointed out, is brought about by removing the electric charges which are situated upon the colloid or emulsion particles and which go to maintain these in a stable sol form. The discharging process is most conveniently carried out by means of electrolytic ions of opposite sign to that possessed by the colloid. The colloid may also be discharged by being carried to an electrode, the discharge at the electrode being presumably quite analogous to the discharge of an ion in ordinary electrolysis. It is of some interest to consider one or two large scale applications of both of these methods of producing coagulation. First of all, coagulation by ions.

A very important application of this is found in one of the methods employed for rectification of current—that is, the transformation of alternating into direct current. In this connection the *aluminum rectifier* is well known. A condenser is placed in the alternating-current line, one plate of the condenser being of aluminum, the space between the plates being filled with an aqueous solution of a salt. On the aluminum plate there is rapidly formed some colloidal aluminum hydroxide, and if this can be made to coagulate and adhere to the plate the current taken off will be unidirectional.

The problem is, therefore, to choose an electrolyte which will most completely effect the coagulation of the colloid. Since aluminium hydroxide is a positively charged colloid the discharging effect must be brought about by an anion, and further as we have seen the higher valency of the ion the more effective it will be. Thus the salts of monovalent acids—such as nitrates, chlorides, acetates, etc., are inefficient. Salt of divalent acids, such as sulphates, carbonates, and tartrates, are moderately efficient. That is to say, a rectifier containing such divalent salts will rectify current whose voltage does not exceed 30-50 volts. If the current is at a higher voltage the rectification is only very partial and incomplete. Using trivalent radicles such as phosphates, citrates, or borates, the efficiency of the rectifier is much increased, as it is now capable of dealing with a pressure of over 200 volts. It is interesting to note, also, that silicates, though strictly speaking belonging to a divalent acid, are exceedingly efficient, no doubt due to the fact that the coagulation is here itself functioning as a colloidal anion though a clear explanation of the mechanism is wanting.

Obviously much investigation remains to be done. It would be interesting to try other colloidal anions of much greater complexity than colloidal silicate, such, for example, as organic, electrolytic colloids like Congo red. The point as to whether the molecular mass of the coagulation is significant as well as its valency also requires investigation.

Another important application of coagulation is met with in the *de-emulsification of water contaminated with oil*, the oil being in the form of an emulsion. It is an important engineering problem, especially in connection with the forced lubrication in steam turbines, and has been solved with some considerable success by the use of alum. The oil particles are negatively charged and can, therefore, be discharged by a cation of high valency such as $Al^{\cdots}$ The alum solution is run slowly into the emulsion, the oil coagulates on the top and may be run off. The result is that a considerable quantity of oil is recovered which would otherwise have run to waste, and at the same time the oil is prevented from fouling the heated parts of the engine. It may be remarked that oils, otherwise very similar, differ much in the ease with which they become emulsified (cf., for example, A. Philip, *Journal Society of Chemical Industry*, 1915, 34, 697).

The next problem to be touched upon is *river sludge* formation and *sewage precipitation*. The fact that material which remains in suspension as long as the liquid medium is fresh water but is deposited when carried to the mouth of a river where the medium is now salt, obviously suggests that coagulation has been brought about by the sodium and calcium salts of the sea water. When this process goes on for centuries formation of deltas results. As a rule, coagulation of this kind is anything but desirable. In other cases, however, notably when a river overflows its banks, the result may be beneficial. The fertility of the Nile valley, for example, may be ascribed to this cause, the rich colloidal matter in the river water being precipitated upon the adjacent soil.

In view of the large amount of sewage annually carried down by rivers the question has been raised as to whether it may be possible to recover by means of regulated coagulation some of the valuable fertilizing materials represented by the phosphorus, nitrogen and potassium contained in the sewage. As a matter of fact, an attempt has been made along these lines in Germany, but so far the efficiency is low. It is nevertheless a very important problem. Our present practice of getting rid of sewage somehow can scarcely be the last word on the subject.

As a final illustration of coagulation by chemical means, that is by ions or even by change in the nature of the solvent by large addition of non-electrolyte, a reference may be made to one or two methods for the *coagulation of rubber latex*. A method suggested by Fulton and Macallum (Eng. Pat. 9066 of 1914) depends as far as I see upon the change in the nature of the medium. The latex suspended in water is treated with aldehydes or ketones other than formaldehyde. As an example 80-90 parts of water are added to 10-20 parts of aldehyde or ketone and the solution may be used with about half its volume of latex which is preferably sprayed over the coagulant. An alternative method of treatment which causes coagulation and at the same time sterilizes the rubber is that proposed by S. C. Davidson (Eng. Pat. 22,138 of 1914). A solution of one part of sodium thiosulphate in 16 parts "alkalised cresol," that is, a solution of cresylic acid in aqueous sodium or potassium hydroxide, is stirred into Hevea latex in the proportion of 1 to 5 per cent. The latex is allowed to stand for 24 hours, and is then coagulated by means of a 1 to 2 per cent solution of sulphuric acid. Other acids, such as acetic, trichloracetic, or hydrochloric may be used. The SO_2 evolved on addition of the coagulating acid possesses a preservative effect upon the rubber.

It is somewhat obscure why it should be necessary to allow the latex to remain so long in contact with the thiosulphate. The thiosulphuric acid may, of course, exert an incipient coagulating action, or it may be that the thiosulphate requires this time to take the place of other salts already adsorbed upon the latex particles. That is to say, it may be a case of preferential or selective adsorption. I have no idea as to how efficient this actual process may be. It serves, however, to indicate how much purely scientific work remains to be done in order to supply us with a larger number of general principles which would serve as guides in this or other colloid problems.

Let us turn now to the alternative method of colloid coagulation by bringing the colloid directly into contact with an oppositely charged metal electrode. This has had up to the present less utility than the ionic method. De-emulsification may be easily effected upon the laboratory scale, but I do not know if it would compare with the alum method on the large scale. The method, however, has been employed for sewage treatment. According to A. M. Williamson (Trans. Amer. Electrochem. Soc., 1915, 27, 193) an installation in America deals with as much as a million gallons of sewage per day. On general grounds one would think that the electrical method should be efficient in that all the colloidal material would automatically separate itself at both electrodes according to the sign of the charge. The method would, however, be more economic of current the smaller the content of electrolytic salts present.

(e) Selective Adsorption

This principle has been made use of in a method proposed for the *separation of radioactive salts* (Ges. für Elektro-Osmose, Eng. Pat. 10,083 of 1914). The salts are in a state of adsorption upon colloid material, this condition being the result of a preliminary treatment. The point is to remove the adsorbed radium salts as completely as possible from the colloid material and from other salts, *e.g.*, barium. This is effected by adding to the colloidal solution certain other salts at suitable concentration. These salts are preferentially taken up by the colloid, the radium salt thus passing into solution.

By way of illustration, a MnO_2 adsorption product of Ra and Ba in a fine state of subdivision is boiled with NH_4Cl solution of certain strength and the solution filtered. On analysis it is found that the solid matter conains 32.7 per cent of the Ba and 64.7 per cent of the Ra originally present. That is, a certain amount of separation of Ra and Ba has been effected. Although a single run leads only to a partial separation the method is interesting and suggestive.

(f) Application of the "Protective" Effect

Reference has already been made to the protective and preservative action of gelatin upon colloidal platinum. In a process patented by the Gesellschaft für Elektro-Osmose (Eng. Pat. 9261 of 1914), the object of which is to *prepare stable colloidal solutions of metals* in general, use is made of *colloidal silicic acid* as the protective colloid. The silicic acid is obtained in a pure state by a method which will be referred to later.

As an example of the procedure adopted, a metal salt, *i.e.*, a silver or gold salt, is reduced by a suitable reagent such as hydrazine hydrate in presence of the silicic acid. A stable solution of silver or gold results, which is purified from the electrolytes by electrolysis. In a later patent (Eng. Pat. 15,267 of 1914) it is claimed that the protective effect of silicic acid can be extended to the preparation of stable metals prepared by Bredig's sparkling method, the instance quoted being nickel. Further applications of the salt-reduction method in presence of silicic acid deal with the preparation of colloidal selenium, palladium and platinum. It would appear, therefore, that the method is a fairly general one.

A further instance of protective effect is to be found in a process for *sizing and coloring parchment paper* (E. Fues, Eng. Pat. 19,816 of 1914). A solution which contains both an acid and a basic dyestuff may in general be regarded as an unstable one. In the presence of some size, however, precipitation can be prevented, the size acting as a protective colloid. The mixtuer of dyestuffs can therefore be successfully applied, in this case, to the paper.

(g) Applications of Electro-osmosis

This is one of the most important branches of applied electro-capillary chemistry. As an example of a general type of problem to which electro-osmosis is applicable one may instance *filter press* work. In this connection F. Ulzer (Z. angew. Chem., 1915, 28, i. 308), describes a process whereby filtration of liquids containing very fine particles can be made without clogging the filter cloth. The filter is of the usual form, consisting of a number of chambers in each of which electrodes are placed. The chambers are first filled with liquid, the current is passed, and the suspended matter wanders to one or other of the electrodes, becomes electrically discharged, and is deposited. The liquid can now be made to pass with relative ease through the filter cloth. Clogging of the latter is thus largely diminished, and hence excessive pressure is not required. The author claims that the method separates the finest particles from liquids and can be used for mineral colors, dyestuffs, barium sulphate, and other suspensions. Strictly speaking, the process is an illustration of cataphoresis and coagulation rather than electro-osmosis, but the arrangement is very similar to that employed in electro-osmotic problems generally.

A second instance is the application of electro-osmosis to the preparation of pure colloids, the case in point being the preparation of *colloidal silicic acid* of low molecular weight, that is, in a state of fine subdivision (Ges. für Elektro-Osmose, Eng. Pat. 9273 of 1914). To begin with, an alkali silicate solution of 5—10 per cent strength is placed in an anode compartment, the electrodes being preferably perforated. When the prod-

uct is to be used medically the anode consists of platinum gauze. Brass wire net serves as the cathode, the electrodes being separated by an electrically neutral membrane, consisting of carborundum and corundum. The process begins with low voltage, which is ultimately raised to 60—70 volts to remove all the alkali from the compartment. The colloidal silicic acid negatively charged,* is precipitated at the anode, the sodium leaving the compartment. Traces of foreign acids present with the silica are removed by transferring the solution to a vessel serving as a cathode and electrolyzing, the anode being surrounded by parchment.

A further illustration of the applicability of electro-osmosis deals with the *tanning of hides* and *impregnation of similar materials*. In the usual method of tanning the material is brought into contact with the tanning liquid under suitable conditions of concentration and temperature, and allowed to remain in contact for a length of time. In the present process (Ges. für Elektro-Osmose, Eng. Pat. 19,849 of 1914) the tanning action is accelerated and possibly improved by bringing the tanning colloid into very close contact with the hide by electrical means. The hide is kept at a suitable potential, positive or negative, and the tanning substance, which is naturally charged, moves up to and is discharged upon the surface. A few details are given in the abstract (this J., 1915, 34, 1021), and are as follows:

"Hide is tanned by electro-osmosis by utilizing the material to be treated as a partition, without fitting it tightly to the walls, to divide the space between suitable diaphragms, the latter being so selected that the active constituents cannot migrate through them, whereas substances affecting the osmotic action unfavorably pass through and are separated from the liquid. Constituents which hinder or delay the process are removed from the hides or skins electro-osmotically by desorption before the actual tanning. During treatment the hides or skins are caused to acquire automatically a potential suitable for the tanning substances used; with tannin this must be of an electro-positive character, with chromium compounds, electro-negative."

As a final example of electro-osmosis we may briefly consider the manufacture of *gelatin for photographic emulsions* (Ges. für Elektro-Osmose, Eng. Pats. 21,448 and 21,484 of 1914). The object is to get a gelatin free from fat and from mineral and reducing constituents. The procedure is as follows: A solution of gelatin inclosed between electrically indifferent diaphragms is subjected to an external voltage. The inorganic ions migrate through the diaphragms in the ordinary way and so are removed. At the same time any albuminoid bodies are coagulated and can be mechanically separated off. The resulting gelatin is thus free from turbidity which sometimes manifests itself owing to the presence of albumin. Exactly the same procedure is applicable to the manufacture of *high grade glue*. Modifications may be introduced in the form of electrically charged diaphragms for the separation of other constituents, thereby yielding a very pure product.

From the survey given above it is evident that the subject of capillary and electrocapillary chemistry is one of great magnitude and importance both from the scientific and from the technical aspects. In the present situation it is plain that technical application has considerably outrun theory, and if future industrial development is not simply to be on empirical lines, it is essential that scientific investigation must be greatly accelerated. At the present time capillary chemistry does not occupy the place it should in our University curricula. But as things stand it is impossible to deal with the subject effectively. From the manufacturers' standpoint, a serious lesson might be drawn from the activities of a single German firm, the Gesellschaft für Elektro-Osmose, from whose patents several illustrative examples have been taken. It is fairly evident that such processes can only be dealt with and extended by proper scientific control. It has been repeated *ad nauseam* that this is the only way to advance not only in regard to the applications of capillary chemistry, but in all applied chemistry. It does not, however, appear, even yet, to have been sufficiently realized.

*It is not quite clear what sign the charge possesses under these circumstances. Usually SiO_2 *sol* is negative, but becomes positive in acid solution.

Muspratt Laboratory,
The University, Liverpool, England.

The Active Materials and Electrolyte of the Alkaline Storage Battery

BY L. C. TURNOCK

The materials that function electrochemically in the alkaline storage battery and are employed in its manufacture are nickelous hydrate, Ni $(OH)_2$, for the positive plates, metallic iron containing a small amount of mercuric oxide, HgO, for the negative plates and an aqueous solution of caustic potash containing a small amount of lithium hydrate as electrolyte.

Preparation of Nickelous Hydrate

Shot nickel varying in size from approximately 1/16 to 1/4 in. in diameter is dissolved in sulphuric acid. The process is continuous, more nickel and acid being added as the solution containing the nickel as sulphate is drawn off. The hydrogen gas evolved in the reaction is retained and conducted to a gasometer; it is subsequently employed in the reduction of ferric oxide to metallic iron.

The nickel sulphate solution contains as impurities small amounts of copper, arsenic, antimony and iron. The bulk of the copper is removed electrochemically by shot nickel, while the remainder together with the arsenic and antimony is precipitated out with hydrogen sulphide gas. The solution is filtered and the iron in the filtrate oxidized to the ferric state with bleaching powder or sodium hypochlorite (NaOCl), the former being used most. The solution is carefully neutralized with soda ash, when the iron precipitates out approximately as a basic sulphate.

The filtrate containing the nickel as sulphate is sprayed by gravity into copper-lined wooden or iron tanks containing a 10 to 15-per cent solution of sodium hydrate, which has been previously brought to the boiling point by means of steam coils placed in the bottom of the tanks. The nickel is thrown down as the nickelous hydrate. The function of spraying the nickel sulphate solution into hot caustic soda is to prevent as far as possible the occlusion of any sulphate by the precipitate, thereby minimizing the amount of subsequent washing required to purify the nickelous hydrate.

The clear liquid is drawn off and the $Ni(OH)_2$ removed as "mud" and filter-pressed by means of wooden filters. The product contains small amounts of sodium sulphate, sodium hydrate, sodium carbonate and water, all of which must be removed. It is placed in pans and dried by steam coils; the temperature is not allowed to exceed 100 deg. C. An analysis of the dried product averages

Water (in vacuum over Sulphuric Acid)	1.33%
Nickelous hydrate	52.54%
Sodium Sulphate	30.34%
Sodium Hydrate	12.41%
Sodium Carbonate (from soda ash)	3.30%

The mass is leached with hot distilled water (steam condensate) ten to twelve times until the wash water shows no test for sulphates, carbonates, nor gives an alkaline reaction. No attempt is made to wash out the impurities from the nickel hydrate "mud." The filter pressing and subsequent steam drying of the product renders it more porous and permits of more efficient washing and in addition the washing is accomplished in a shorter period.

Following the washing of the nickelous hydrate it is dried by steam coils, the temperature not being allowed to go over 100 deg. C. The product is now tested for its electrical capacity (see below) and if found up to standard ground up in 500-lb. batches. Of the screened material that which is desirable comes between 30 and 190 mesh. The allowable limits for acceptance of material is not over 6 per cent through a 190 mesh sieve and not over 15 per cent upon a 30 mesh sieve. All of the ground product generally passes a 20 mesh. The material is now ready for loading into the tubes that constitute the positive plates of the battery.

Preparation of Metallic Iron

The purest iron obtainable (generally a Norway or Swedish product) is employed as a starting product; it shows on analysis traces of manganese, phosphorus, silicon and sulphur with carbon as low as 0.02 to 0.03 per cent. The raw material is placed in lead-lined digesters and treated with sulphuric acid. The gases evolved, consisting of hydrogen, hydrocarbons and hydrogen sulphide are conducted through a purifying train containing sodium hydrate to remove the hydrogen sulphide and chromic acid to remove the hydrocarbons. The hydrogen is conducted into the same gasometer in which is stored the hydrogen obtained as a by-product in the purification of the nickel. The resulting ferrous sulphate solution is drawn off and crystallized and re-crystallized several times, after which the crystals are put into a centrifugal machine to free from the mother liquor and subsequently into rotary driers fired with fuel oil to a temperature of 200 to 300 deg. C.

The dried and slightly calcined ferrous sulphate is placed in muffle furnaces and given an oxidizing roast. The resulting product is ferric oxide (Fe_2O_3), which is leached out with water to remove traces of ferrous sulphate not affected by the roast. After drying the oxide of iron is placed in iron retorts and set in a muffle furnace and reduced to metallic iron by the hydrogen obtained above. As an index to determine when the reduction of the ferric oxide is complete the charge is weighed as put in and the moisture formed in the reaction condensed, collected and weighed.

The vessels containing the metallic iron are removed from the furnace and allowed to cool in an atmosphere of hydrogen gas to prevent almost spontaneous ignition back to the oxide. As a further precaution against reversion back to Fe_2O_3 a dilute solution of NaOH (to prevent rusting) is run in on top to cover the iron when the pan is opened. The product is allowed to stand five to six hours in the sodium hydrate solution, when it is drained and dried slowly by heat. After grinding and mixing with 6 per cent of yellow oxide of mercury (which is prepared by dissolving mercury in nitric acid and precipitating it out again with NaOH solution) it is ready to be tested for its electrical capacity and if found up to standard loaded into the pockets that make up the negative plates of the battery.

The beneficial action of the mercuric oxide in maintaining the activity of the iron appears to be more or less empirical in character. It is reduced to metallic mercury during the charging of the battery as is evidenced by the fact that an examination of the sediment in the bottom of the containers of cells that have been in service for some time frequently discloses the presence of appreciable amounts of metallic mercury that have fallen from the pockets. Small amounts of iron oxide that may be present in the iron through an incomplete reduction of the Fe_2O_3 will lower the capacity of the latter; the presence of mercury seems to counteract this detrimental effect. Moreover, metallic mercury will increase the electrical conductivity of the mass.

Preparation of Electrolyte

The electrolyte employed is made up according to two sets of specifications. One calls for "first" electrolyte, which goes into the cells after assembly, and consists of an aqueous soluton of potassium hydroxide (21 per cent by weight) containing 50 grams of lithium hydrate per liter of finished electrolyte. This amount of lithium hydrate represents its maximum concentration in a 21 per cent KOH solution at 24 deg. C. The specific gravity of "first" electrolyte is about 1.230 at 20 deg. C.

The second specifications call for "renewal" electrolyte, which is supplied for renewal after the cells have been in more or less continuous service for about a year. It is made up of an aqueous solution of KOH (25 per cent) and 15 grams of LiOH per liter of finished electrolyte. Fifteen grams of lithium hydrate, likewise, represents the maximum concentration in a 25 per cent potassium hydrate solution at 24 deg. C. The total alkalinity of such a solution, computing the LiOH in equivalence of KOH, is 27.8 plus or minus one-half per cent.

The potassium hydroxide employed is an electrolytic product of potassium chloride and is received as a solid in iron drums. It is dissolved and diluted to a 33 per cent solution and subsequently to solutions corresponding to 25 and 21 per cent, respectively. The specific gravity of the solution is employed as a measure of its strength; 21 per cent KOH has a specific gravity of 1.2026 at 17.5 deg. C. and 25 per cent KOH of 1.248 at 20 deg. C.

The lithium is obtained as the carbonate and dissolved in water in large steam-heated iron kettles and treated with lime (CaO) and hot water. The following reaction occurs:

$$Li_2CO_3 + Ca\ (OH)_2 = CaCO_3 + 2LiOH$$

The calcium carbonate is allowed to settle and a solution containing about 4 per cent LiOH is obtained; it is bluish in color and very caustic. The 4 per cent LiOH solution is concentrated down until about a 12 per cent soluton is obtained, when it is analyzed for its LiOH content and its gravity taken. The calcium oxide (CaO) is obtained by calcining a very pure grade of limestone in a kiln fired by producer gas and air.

The following example illustrates the method of computing and making up the electrolyte according to specifications:

Given a 33 per cent KOH solution having a specific gravity of 1.320 and 12 per cent LiOH solution having a specific gravity of 1.14.

Required to find the proportion in which to mix the above two solutions in order to obtain a solution containing 21 per cent of KOH and 50 grams of LiOH per liter of finished electrolyte.

Solution.—One liter of 33 per cent KOH contains

$$1.320 \times 1000 \times 0.33 = 435.6 \text{ grams KOH}$$

1 liter of 21 per cent KOH (Sp. Gr. equals 1.202) contains

$1.202 \times 1000 \times 0.21 = 252.42$ grams KOH

Therefore, volume of 33 per cent KOH solution required to supply 252.42 grams of KOH equals

$252.42/435.6 \times 1000 = 579$ c.c.

1 liter of LiOH solution contains

$1.114 \times 1000 \times 0.12 = 133.68$ grams LiOH

Therefore, volume of 12 per cent LiOH solution required to supply 50 grams of LiOH equals

$50/133.68 \times 1000 = 374$ c.c.

Hence, specifications for 1 liter of 21 per cent KOH plus 50 grams per liter is

33 per cent KOH........579 c.c.
12 per cent LiOH........374 c.c.
Water (supplied)....... 47 c.c.

The specifications for making up the solution containing 25 per cent KOH plus 15 grams of LiOH per liter is obtained in a similar manner.

While the battery is in service more LiOH appears to enter the plates on discharge than is given out on charge. Inasmuch as the lithium hydrate seems to exercise a beneficial effect upon the battery in proportion to the amount present in the electrolyte, it is desirable to maintain the concentration of the LiOH at a maximum. For this purpose crystals of lithium hydrate (containing about 54 per cent LiOH), and varying in amount from about 9 grams for the smaller sizes of batteries to over 100 grams for the larger types, are placed in the cell after assembling and just before the "first" electrolyte is added.

Testing of the Nickelous Hydrate and Iron for Electrical Capacity

By electrical capacity of the active material is meant the length of time a certain amount of it, loaded into tubes or pockets similar to those constituting the finished plates, will deliver a specified current by the time its potential falls to a certain predetermined value. The selection of this value is entirely arbitrary and is influenced by the electromotive force characteristics of the two electrodes upon discharge and by the performance of motors, or other electrical appliances to be operated, under the decreasing potential gradient of the battery. It is usually selected to conform to conditions encountered commercially and down to which the battery will show its best service; if allowed to fall lower, it will have little or no practical importance.

Theoretically, a cell containing 1.042 grams of iron and 1.725 grams of nickelous hydrate will furnish 1 amp.-hr., but after a discharge of 1 amp.-hr. it will have no capacity, and its potential will have dropped to a value which cannot be utilized at all. Practically, the battery must have enough excess active material in its construction to insure its potential not falling below a certain arbitrary value while discharging at a certain desired rate and immediately after it has delivered its predetermined capacity in ampere-hours.

Another important factor which affects the available capacity of the battery is temperature. The potential of the battery when delivering its normal rate current is a function of its internal resistance and decreases with increase of resistance. A rise in temperature, however, will decrease the internal resistance and thereby allow of a greater ampere-hour output before the cell will have reached the predetermined cut-off voltage. Consequently, in determining the electrical capacity of the nickel hydrate and iron it is essential that the temperature at which the test is made is the same as that under which the standard test was made. In order to fulfil the requirement that the cell will not drop below a certain potential before it delivers its rated output, approximately 4.64 times as much $Ni(OH)_2$ and 5.78 times as much iron are used in the construction of the different plates as the theoretical minimum.

To determine whether or not the active material as manufactured is standard in capacity, tests are made with miniature cells. Those for testing the hydrate of nickel are composed of one tube loaded with the hydrate under question and two pockets, containing some standard iron, mounted on either side of the hydrate tube. Those for testing the iron consist of one pocket containing the iron under question together with two tubes, one mounted on either side of the iron pocket, containing some standard nickel hydrate.

The nickel hydrate is placed into a standard-size tube by an automatic loading machine, which alternately adds and tamps in the hydrate of nickel and flake nickel (very thin squares of metallic nickel about 0.00004 in. thick and 1/16 in. on the edge). The weights of both entering the tube are noted; the flake nickel averages from 13 to 14 per cent of the weight of the total contents.

The electrolyte employed for the test cells is a 21 per cent KOH solution containing 11.2 grams of LiOH per liter of finished electrolyte. Based on their relative capacities the amount of electrolyte employed in the test cells is greater than that used in the commercial sizes; hence, an electrolyte containing less lithium hydrate is employed.

The charging and discharging rates used represent practically the same current density as that recommended for the larger types.

A loaded tube, 3 in. in length, will contain about 7.75 grams of both nickel hydrate and flake nickel in approximately 265 alternate layers of each.

The cell is put on three cycles of charge and discharge at room temperature, charging for 15 hr. at 300 mil-amperes and discharging at 200 mil-amperes down to a terminal voltage of 0.9, noting the capacity in mil-ampere hours in each case. The available capacity will usually increase after each cycle; this is no doubt due to increased penetrability of the active mass by the electrolyte, thereby rendering more of it active. The first three runs are followed by ten cycles of charge and discharge, the cell being kept at a temperature of about 54.5 deg. C.; it is discharged to zero voltage in each instance.

The operation of the cell at such a temperature, which is rarely attained in practice, is thought to hasten its deterioration and multiply the severity of the service it will ordinarily be put to under commercial conditions. At higher temperatures, moreover, tests show that both the nickel hydrate and iron have a low effective input on charge, the former exhibiting this phenomenon more decidedly than the latter; obviously, this would result in a lower available capacity. As a matter of fact, however, four subsequent runs similar to and at the same temperature as the first three generally show the cell to have increased in capacity. Such a cell must show at least 1100 mil-ampere hours before the active material is accepted.

For testing the activity of the iron approximately 5 grams are placed in one of the standard pockets and mounted in a test cell. For the first three runs it is charged for 15 hr. at about 0.4 amp. and discharged at 0.3 amp. down to 1.0 volt, noting the capacity in each instance. On the next three runs it is charged at 0.4 amp. and discharged at about twice the former rate down to 0.5 volt, noting capacities

at both 1.0 and 0.5 volts. This is generally followed by two cycles of charge and discharge at same rates as employed for the first three runs, noting the available capacity at both 1.0 and 0.5 volt. A procedure of this character will demonstrate the desirability of the iron. A pocket containing 8 grams of acceptable iron will show better than 1900 mil-ampere hours discharged to 1.0 volt.

An analysis of the terminal voltage of the battery discharging at its normal rate, as typified by the employment of an auxiliary electrode, shows that the potential of the negative plates, or those originally containing iron as active material, is practically constant. This is indicative of the fact that the iron, in addition to being present in greater equivalent amounts, is more active electrochemically than the nickel hydrate, no doubt due to its greater porosity and consequent greater accessibility to the ions of the electrolyte.

This is further substantiated by the fact that the curve representing the difference of potential on discharge between the positive plate, or that originally containing the nickelous hydrate as active material, and the auxiliary electrode has the same general shape as the curve showing the terminal voltage on discharge at normal temperatures. The available capacity of the battery is limited by the behavior of the positive plates on charge and discharge.

Furthermore, owing to the material composing the positive plates having a small electrical conductivity as compared with that composing the negative plates, very thin flakes of metallic nickel are incorporated with the nickelous hydrate in alternate layers in the tubes, pressure being applied after each separate addition to insure more intimate contact between the active material and the walls of the tube; such a process increases the conductivity of the mass as a whole. Obviously, a decrease in electrical resistance cannot be secured by this means except at a sacrifice of the porosity of the active material and consequent accessibility of the electrolyte ions to the interior of the mass.

Carnegie Institute of Technology,
Schenley Park, Pittsburgh, Pa.

Synopsis of Recent Chemical and Metallurgical Literature

Conveyor Belts

Testing of Conveyor Belts.—From an extended paper on conveyor belts for metallurgical plants, published by A. Robertson and A. McArthur Johnston in the *Journal* of the South African Institution of Engineers, we take the following excerpt relating to methods of testing conveyor belts. The authors advocate the practice of such tests in order to raise the standard of materials used, and as a protection against poor material and excessive charges.

Balata Belts

Balata belts are tested by determining the strength of the warp and filler of the canvas, and by ascertaining the frictioning or adhesion between adjoining plies or layers. In belting the main strength must lie in the warp, though that of the filler should be but little inferior. This strength is found by breaking in the tension machine a section of the belt one inch in width. Care must be taken in cutting this that no thread in the line of the pull be broken before the test.

(1) *Strength of Cotton Duck.*—When for some reason only one ply can be obtained for this test it is advisable to cut a section just over an inch, and detach therefrom single strands until the exact inch is got. The grips also must bear evenly over a surface, so as to avoid pinching the belt in one place; this may be partly avoided by making the gripped portion larger than an inch—say one and a half inches, with a taper to one inch. The tested portion should be, over the inch section, at least three inches in length.

A specification for the cotton duck used in this belting should note:

(a) The weight of duck used (ounces per linear yard).

(b) The number of yarns per inch, both for warp and for filler.

(c) The tensile strength of the warp and of the filler.

(d) The amount of stretch in the belt.

(e) The number of plies in the belt.

To illustrate the variation that exist among this class of belting, the samples being submitted for one particular duty, I may quote the following results:—

Samples tested lengthways of belt (warp). Tensile Strength of Total Belt, one inch in width.

		Number of Ply
(a)	2,806 lb	8
(b)	3,180 lb	6
(c)	3,168 lb	8
(d)	3,564 lb	6
(e)	3,600 lb	4
(f)	3,916 lb	8
(g)	3,136 lb	8
(h)	1,320 lb	6

If we neglect the last one as being an inferior lot, we still find a variation amounting to over half a ton per inch in the breaking strain of the different duck used; this means an additional load capacitiy of 15 tons on a 30 in. belt.

The tensile strength of the filler in certain belts examined shows proportionately even greater differences.

Samples tested, one inch in width.

		Number of Ply
(i)	990 lb	6
(j)	1,440 lb	8
(k)	2,288 lb	10
(l)	1,980 lb	8
(m)	1,584 lb	8
(n)	1,584 lb	8
(o)	1,232 lb	8

The difference of a breaking strain of 750 lb. per one inch section in the filler of two eight-ply belts is surely worthy of consideration when placing an order.

It is to be noted that the strength of the warp is greater than the filler, and agents should note in submitting samples for test that these be at least 10 to 12 inches in length and about 3 to 4 inches in width, except when the strength of both warp and filler is required, in which case the section submitted should be 10 inches square.

(2) The *adhesion* between adjacent plies of duck is determined by maintaining a steady pull in separating these. A section of the belt one inch in width is taken, and one, or even two or three, of the plies is separated by hand from the remainder for a length of two inches, and the two ends caught in the clamps of the machine shown in Fig. 1 (testing machine). A steady pull is applied by turning the wheel, the rate of turning being regulated so that the jaws may move apart two inches per minute.

The spring balance registers the resistance set up and indicates the effectiveness of the Balata frictioning. The adhesiveness depends on the quality and quantity of the Balata used and the success of the operation known as frictioning.

The Pennsylvania Railroad Company require that the frictioning of their air brake hose be such as to support a pull of 25 lb. while separating at approximately the above rate. Many air hoses on our market scarcely maintain a 11-lb. pull when separating contiguous plies.

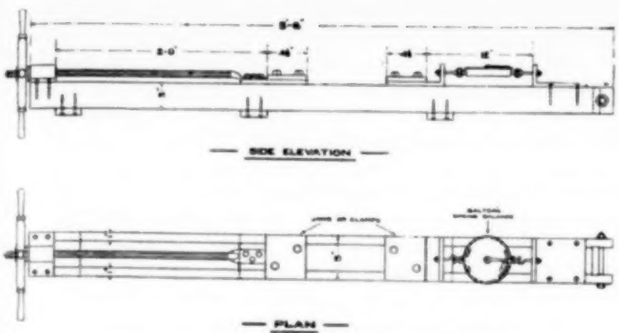


FIG. 1—TESTING OF CONVEYOR BELTS

A specification for Balata belts might well demand a friction test of at least 20 lbs. This figure is not often reached here, but if demanded it could easily be got, and would form some guarantee that the belt plies would not readily come asunder.

The follcwing results from a series of tests show actual figures on samples of Balata belt at present in this market:—

Friction Tests

	Lb.
(1)	24½
(2)	21½
(3)	21
(4)	18½
(5)	17
(6)	16½
(7)	15
(8)	14
(9)	13
(10)	12
(11)	11
(12)	5

(3) The *stretch* in the belt is not often determined in the testing laboratory, though, given suitable apparatus, this could be easily done. It is always advisable to test the belt as a whole and not over an inch section.

Rubber Conveyor Belts.

Similar tests are made on rubber conveyor belts, with, of course, the additional testing and analysis of the rubber.

(1) *Canvas Strength.*—Owing to the greater cost of rubber belting, firms are not keen on supplying test lengths of 9 to 12 inches, and as a rule tests of the cotton duck are made on the transverse section. One sample of a very good belt submitted here gave the same tensile strength longitudinally as transversely, but this result would not always be found.

The following are the records of the *total strength* of the cotton duck of seven belts recently examined here:—

		Lbs.
A.	Tensile strength on 1 in. transverse section (6 ply)	902
B.	Tensile strength on 1 in. transverse section (6 ply)	858
C.	Tensile strength on 1 in. transverse section (6 ply)	924
D.	Tensile strength on 1 in. transverse section (6 ply)	825
E.	Tensile strength on 1 in. transverse section (6 ply)	1,050
F.	Tensile strength on 1 in. transverse section (6 ply)	996
G.	Tensile strength on 1 in. transverse section (6 ply)	1,350

The *friction tests* on these same seven samples showed that none of them were exceptionally good, while one was exceedingly bad, and three poor. The tests were made on a one inch transverse section.

		Lbs.
H.	Friction test between cotton duck layers	10
I.	Friction test between cotton duck layers	14½
J.	Friction test between cotton duck layers	1½
K.	Friction test between cotton duck layers	15
L.	Friction test between cotton duck layers	8½
M.	Friction test between cotton duck layers	9½
N.	Friction test between cotton duck layers	6

As these results were obtained from belts which are reckoned the best on our market, it would seem that neither the cotton duck used nor the frictioning are as strong in rubber conveyor belts as in Balata belts.

(2) *Rubber layer.*—The value of the rubber layer depends entirely on the quality of the rubber used, on the vulcanizing it has received, and on its age. One has to handle rubber constantly to realize the depreciation that takes place in this climate, and more especially with the quality of the rubber used for this class of work. It is in my opinion essential in buying a belt to stipulate that it has been but recently imported. Not only does the rubber deteriorate, but the frictioning material used to cement it to the duck loses its adhesive properties.

Two belts which were tested here showed that the rubber layer in each case lost its elasticity to a not inconsiderable extent after a lapse of six months.

Thickness of layer, 3/16 in.

Elongation of a section 1 in. wide and measuring 3 in. between the grips, before breaking.

O.	14/9/14	13 in.	18/3/15	6 in.
P.	14/9/14	8 in.	18/3/15	5½ in.

The following results were obtained from seven samples of rubber conveyor belts:

	Incombustible Matter in Rubber, per Cent	Stretch of 3-In. Test Piece, Inches	Friction Test Between Rubber Layer and Canvas, Layer, Lb.
Q	48.30	13	12
R	46.05	4¾	3
S	42.00	10	9½
T	63.40	5½	6½
U	37.07	9½	14
V	44.04	8	9
W	59.34	......	....
X	39.00	8½	15

Sample W.—The rubber layer in this sample refused to be detached from the canvas layer. As soon as a grip could be obtained and a moderate pull exerted, the rubber tore showing both the poorness of the quality and the effect of climatic conditions.

The elasticity or stretch in the rubber layer is obtained by gripping a section 1 in. wide in the machine used for the friction test, with a distance of 3 in. between grips. The total elongation before breaking or tearing is thus obtained, as is also the tensile strength of the rubber. The following may be quoted as characteristic tensile strengths of a 1-in. section of the rubber layer of belts in good or fairly good condition and ready for the market here:

	Stretch of Rubber (3 In. Between Grips), In.	Tensile Strength, Lb.
(a)	10	83
(b)	7	67
(c)	12	120
(d)	5½	42
(e)	8	105
(f)	9½	60
(g)	8½	310

It would be recommended, therefore, that a specification should demand:

(a) That the incombustible matter in the rubber layer be under 50% by weight.

(b) That a section of the rubber layer 1 in. in diameter shall stretch to at least three times its own length before breaking (3 in. to 9 in.).

(c) That the frictioning between any two contiguous layers, rubber and canvas or canvas and canvas, be at least 15 lb.

It is probable that in time these demands could be made more stringent.

Plastic Flow

Laws of Plastic Flow.—Information on plastic flow is important to many industries. The Bureau of Standards has recently conducted investigations on the laws

of plastic flow and published the results as Scientific Paper No. 278. The author of the paper is EUGENE C. BINGHAM. The property of plasticity, like ductility or malleability, is not at present strictly definable, although the term is much more familiar than the strictly defined terms "viscosity" and "fluidity."

In the study of plastic flow it has already been shown that most homogeneous solids will flow somewhat after the manner of liquids, if subjected to sufficient pressure. Copper, steel, lead, ice, menthol, glass, and asphalt fall in this class in so far as they may be regarded as homogeneous solids. But ordinarily plastic substances are not homogeneous solids, but suspensions of finely divided solids in fluids, such as paint in oil, lime in water, and especially clay in water. Numerous papers have been devoted to the explanation of this latter type of plasticity.

Since glass and other similar bodies are often regarded not as solids but as very viscous liquids, the demarcation of viscous flow from plastic flow has not been sharply made. In fact, attempts have been made to give numerical values to the viscosity of ice, menthol, glass, and pitch, and Tammann defines plasticity in a perfectly definite manner as the reciprocal of viscosity —in other words, plasticity and fluidity are synonymous.

Unfortunately, for the sake of simplicity, this definition is clearly untenable. If any finely divided solid, such as clay, be suspended in a liquid, the fluidity is lowered rapidly and in a perfectly linear manner, so that at a comparatively low concentration of clay the fluidity, as measured in the ordinary viscometer, approaches zero. Thus Durham and Bingham found that a certain clay suspended in water gave a zero fluidity when the volume percentage had reached 6.95 (14.6 per cent by weight), this being independent of the temperature. This concentration apparently serves to sharply demarcate plastic from viscous flow. Suspensions more dilute than this critical concentration are subject to viscous flow, while those containing more solid in suspension are plastic.

The experiments of Bingham and Durham support the definition of Maxwell that a plastic body is one in which the form of the body is found to be permanently altered when the stress exceeds a certain value. However, the laws of plastic flow must be known before a rational basis can be obtained for the quantitative measurement of plasticity. The work of the bureau, which was done chiefly on English china clay, is summarized as follows:

The various types of viscous and plastic flow have been considered theoretically. According to the circumstances of the flow the viscosities may be additive, the fluidities may be additive, or slipping or seepage may enter in to affect the character of the flow. The possible separation of the components of a mixture by means of flow has been considered. It has been shown that in a suspension of solid particles in a liquid there must be a dissipation of energy when the solid particles collide, as they must collide if the layers of the suspension move over each other. This dissipation of energy follows the laws of ordinary friction and not the laws of viscosity.

Measurements have been made upon the flow of clay suspensions of different concentrations through capillaries of varying dimensions and at two temperatures.

It is shown that plastic flow can be sharply differentiated from viscous flow by the "friction" necessary to start plastic flow. The friction is a linear function of the volume concentration. It is also affected by the presence of alkalies or acids, but it is independent of the length or diameter of the capillary as well as the temperature of the medium.

For medium pressure the rate of efflux is given by the formula

$$v = K(P - f),$$

where P is the pressure, f is the friction, and K is an arbitrary constant. The experiments indicate that at low pressure seepage takes place causing a perceptible change in the concentration, and that at high pressures there is slipping which under certain circumstances may cause a sudden increase in the rate of flow.

The fluidity becomes zero at the concentration of solid where the plastic flow begins; that is, where the friction begins to have a positive value. This concentration, where the particles are able to form a bridge across the capillary space, is reached long before the concentration corresponds to close packing of the solid particles. For very fine-grained material the range between the cencentration giving zero fluidity and the concentration corresponding to close packing will be much greater than in coarse-grained material.

The "mobility" of suspensions has been defined and calculated. The mobility decreases very rapidly from its maximum value in the concentration which has zero fluidity to a value not far from zero in the mixture which corresponds to close packing of the solid particles. The mobility increases with the fluidity of the medium, but is also greatly affected by the presence of alkalies or acids.

Recent Chemical and Metallurgical Patents

Iron and Steel

Accurate Determination of Critical Point During Annealing.—An apparatus for accurately determining the critical point during the annealing operation, and thus affording a more accurate control of the grain size and other properties of iron and steel, is patented by ROY B. FEHR of State College, Pa. The method consists in magnetizing the work under treatment and noting any quick change in the magnetization by a milli-voltmeter. When iron or steel reaches the critical point it is no longer magnetic, and thus this point can be determined accurately and need not be estimated or a thermo-couple with its inherent temperature lag need not be depended on, which give varying results in heat treatment.

The apparatus used is shown in Fig. 1. An ingot P is placed in an electrically heated resistance furnace 4. The furnace here shown is heated by a core of nichrome ribbon 3 wound around refractory material. An iron yoke 6 is connected with the ingot, and the yoke is magnetized by the coil connected with resistance 13. A milli-voltmeter 10, connected to copper coil 11, serves to indicate the critical point.

In operating, to find the critical point of the heat curve, the exciting current is adjusted by the rheostat 13 until the ammeter reading is of a proper value to produce a flux of suitable density in the magnetic circuit. The switch 12 is then closed, and the reversing switch 9 is opened; the momentary large deflection of the milli-voltmeter is then read. This reading is proportional to the change in magnetic flux from, say, plus 14,000 units with the magnetizing current to a "residual" flux of, say, plus 7000 units with no magnetizing current. Switch 9 is then closed in the opposite direction, and a reading is obtained corresponding to a change in flux from plus 7000 to minus 14,000 units. These operations are repeated at regular intervals during the heating process, and thus there may be obtained two sets of observations, one set for breaking the circuit and the other for making the circuit. One set would be sufficient, but the other set gives a reliable

check on the work. When the readings in either set suddenly begin to increase or decrease (according to whether the magnetic induction is above or below the "knee" of the saturation curve of steel) I have a positive indication that the metal in the hottest part of the furnace is becoming non-magnetic and ready for heat treatment. (1,188,430, June 27, 1916.)

Operation of Reverberatory Iron-Melting Furnaces.—In melting iron for foundry use in reverberatory furnaces, a uniform temperature from day to day is very desirable. In operating these furnaces in natural draft, difficulty is experienced in obtaining uniform heat due to changing atmospheric conditions. In order to obviate this difficulty JOHN A. SWINDELL of Pittsburgh, Pa., proposes in a recent patent, to operate on a natural draft at the beginning, and when the iron reaches its full melted condition, the ash pit doors are closed and forced draft put on. In this manner uniform heats are claimed to result. To prevent the formation of clinker at the grate, and also to relieve the cutting action on the furnace lining, due to the forced draft, steam may be introduced underneath the grate. (1,188,111, June 20, 1916.)

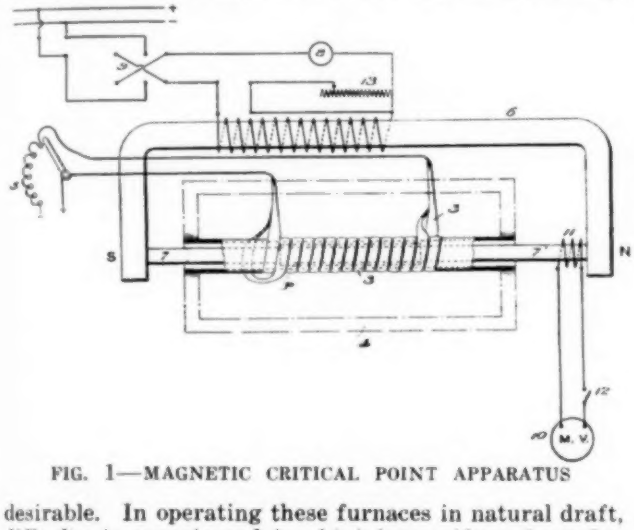


FIG. 1—MAGNETIC CRITICAL POINT APPARATUS

Production of Ferromanganese.—An electric furnace process for producing ferromanganese from waste clinker or cinder from zinc furnaces, and also recovering the zinc, is patented by HARRY SCHAGRIN of South Bethlehem, Pa. The furnace in which the process may be carried out is shown in Figs. 2 and 3.

The waste clinker or cinder from zinc smelters using franklinite or willemite ores, containing 15 to 22 per cent MnO, 28 to 56 per cent FeO, 20 to 30 per cent SiO_2, 8 per cent C, 6 per cent Al_2O_3, 10 per cent CaO, and about 4 to 5 per cent ZnO, is crushed to a suitable size, mixed with 25 per cent by weight of waste coal dust, and a quantity of limestone flux. The charge is placed in hopper 6, and fed by the screw conveyor to the furnace stack. When a sufficient amount of the charge has accumulated around the electrodes, the current is turned on and the temperature brought up to 1500 deg. C. while charging continues. The charge melts, forming the molten pool 20, when the iron and manganese settle down and the slag rises to the top.

The zinc in the charge is volatilized and is drawn off by suction through openings 21 to chamber 23, where it settles. Any zinc passing up beyond the pipes is caught and condensed by the downcoming charge, which is cool at the top and returned to the fusion zone. A reducing atmosphere is maintained in the furnace, and the temperature is not allowed to rise much over 1500 deg. C. It is claimed that the process avoids serious loss of manganese, and works well on low manganese material. (1,190,679, July 11, 1916.)

Production of Silicospiegel.—A modification of the above process as adapted to the production of silicospiegel is described in another patent of HARRY SCHAGRIN. In this case the charge is substantially the same, but the temperature is raised to 1800 to 2000 deg. C. The zinc is volatilized and collected as before, and silicon is reduced along with the iron and manganese, producing on the hearth an alloy containing from 10 to 15 per cent silicon, 10 to 20 per cent manganese, 15 per cent aluminium, and 60 to 70 per cent iron. (1,190,678, July 11, 1916.)

Electrochemistry

Manufacture of Aluminous Abrasives.—A process of making aluminous abrasives which aims to avoid the intermittent running of the furnace and to make the process more continuous is patented by THOMAS B. ALLEN, of Toronto, Can. The patent is assigned to the

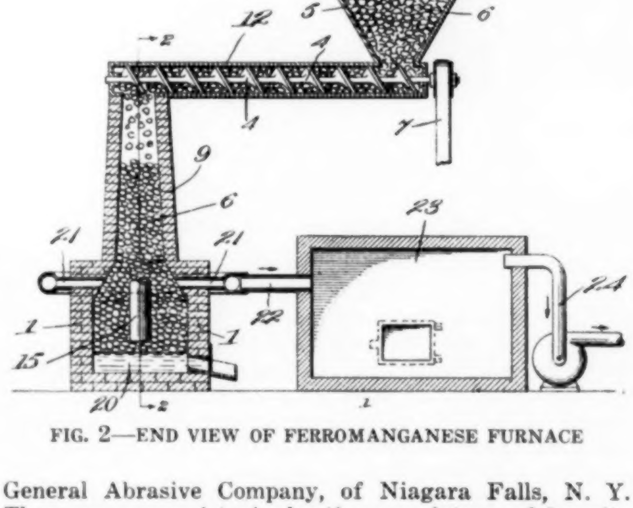


FIG. 2—END VIEW OF FERROMANGANESE FURNACE

General Abrasive Company, of Niagara Falls, N. Y. The process consists in heating a mixture of bauxite and coke in an electric furnace, and tapping separately the resulting abrasive and by-product such as ferrosilicon. The by-product is formed as a result of the reduction of iron, silicon and titanium oxides contained in the bauxite. In Fig. 4 is shown a furnace in which the process may be carried on. *A* is a brick foundation, *B* is a lining made of a mixture of coke and tar, *F* is a tap hole for abrasive, *G* is a tap hole for ferrosilicon. Carbon electrodes are shown at *C*. Polyphase current

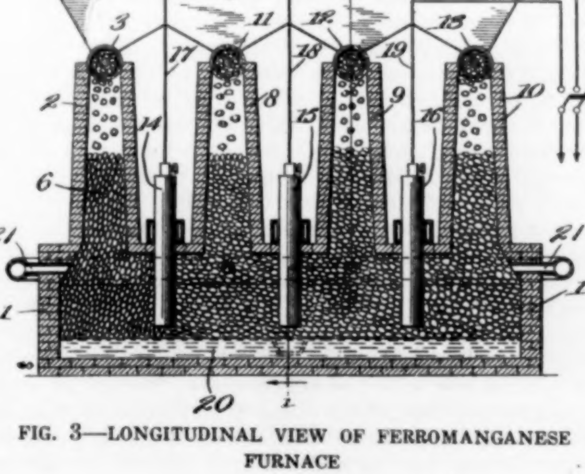


FIG. 3—LONGITUDINAL VIEW OF FERROMANGANESE FURNACE

is preferably used with the necessary number of electrodes.

The charge is made up of 100 parts by weight of calcined bauxite, to nine parts of coke. These are both ground fine and intimately mixed. The mixture is charged and heated in the furnace until 7000 to 8000 lb. is melted and reduction has taken place, which can be judged by the appearance of the molten mass. As soon as reduction is complete and sufficient time elapsed for the settling of the ferrosilicon, the abrasive in molten form is removed by means of the tap hole *F* and

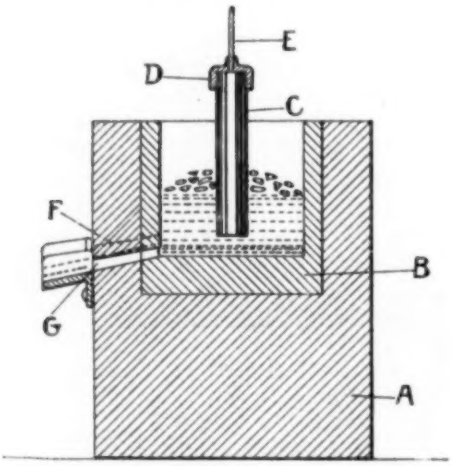


FIG. 4—ALUMINOUS ABRASIVES FURNACE

cast into ingots of a size determined by the quality desired in the abrasive produced. After its removal the ferrosilicon is tapped out by means of the tap hole *G*. The process is then repeated before the furnace cools. The abrasive after cooling is crushed up into suitably sized grains and is then in shape to be used for abrasive purposes. (1,187,225 June 13, 1916.)

Electric Furnace.—An electric furnace which is rotatable horizontally about a vertical axis and which may also be tilted for pouring the charge is patented by PETER EYERMANN, of Witkowitz, Austria-Hungary. A sectional view of the furnace is shown in Fig. 5. The crucible 1, is made of any suitable refractory material and is supported on a frame or cradle 5, by means of annular ball bearings 2, and an upright pivoted bearing 24 at the axis of rotation of the crucible. The crucible is rotated by means of a worm 10, which is driven by an electric motor. The frame and crucible may be tipped for pouring by rocking on the base 27 by means of hydraulic mechanism, as shown at 23. The electrodes 8, extend through the roof as shown. They may vary in number and are so arranged on the roof that the center line of the group, represented by the line 19-19, will be eccentric with regard to the axis of rotation of the crucible, represented by the line 3-3, so that when the crucible is rotated on its axis, each of the electrodes describes a different path, thus subjecting the various parts of the metal to the action of the current. This feature is claimed to necessitate only a small number of electrodes. (1,189,356, July 4, 1916.)

Electrolytic Cell for Magnesium.—A method of production of magnesium or other alkali metals by electrolysis so that the metal collects in considerable amounts is described in a patent of CHRISTIAN DANTSIGEN of Scotia, N. Y., which is assigned to the General Electric Company. The feature of the cell is a cathode which will alloy slowly with the magnesium. The cell is made of magnesite brick, and a fused electrolyte of potassium chloride and magnesium chloride in molecular proportions, to which may be added 2 or 3 per cent of calcium fluoride is used. Anodes are of carbon, and cathodes are of sherardized iron, copper-coated iron or tin-coated iron. Any of these will allow slowly with the magnesium and produce large masses of magnesium at the cathode. The molten metal wets the surface of the zinc-iron alloy, and hence remains attached. An advantage is gained if several cathodes are used in one cell as a more effectual collection of the magnesium takes place. The

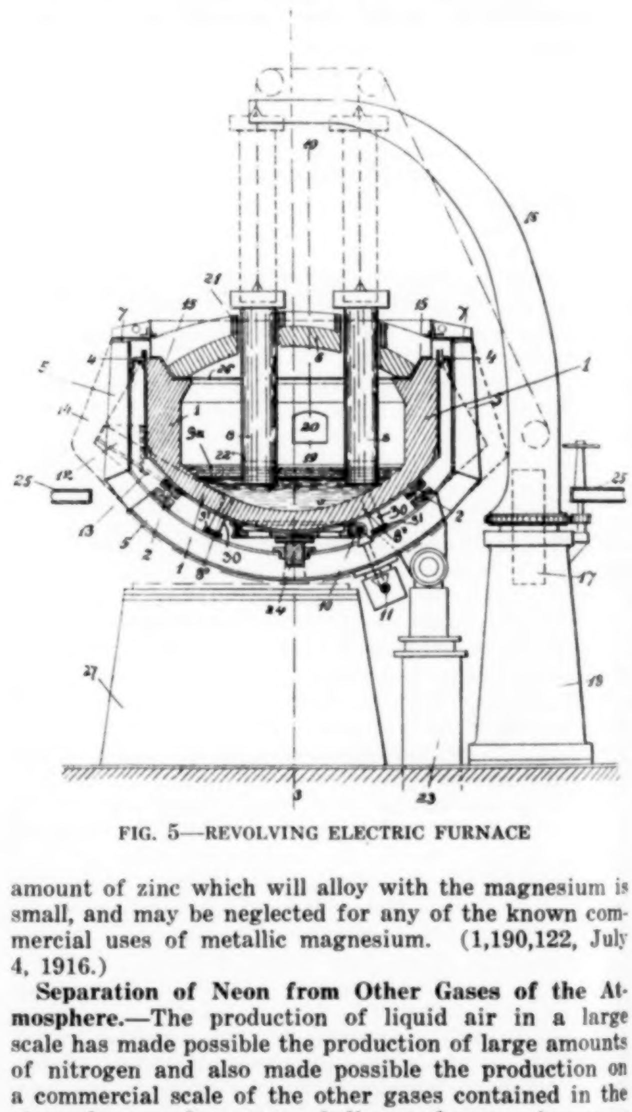


FIG. 5—REVOLVING ELECTRIC FURNACE

amount of zinc which will alloy with the magnesium is small, and may be neglected for any of the known commercial uses of metallic magnesium. (1,190,122, July 4, 1916.)

Separation of Neon from Other Gases of the Atmosphere.—The production of liquid air in a large scale has made possible the production of large amounts of nitrogen and also made possible the production on a commercial scale of the other gases contained in the atmosphere, such as argon, helium and neon. A process of separating neon from the other gases mixed with it, more particularly helium, is patented by GEORGES CLAUDE of Boulogne-Sur-Seine, France. A tube such as shown in Fig. 6 contains carbon electrodes *g*, and connections *m* and *n* for a vacuum pump and impure

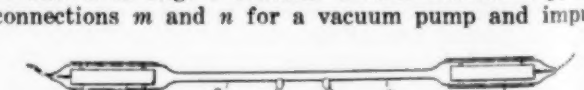


FIG. 6—NEON PURIFYING TUBE

neon respectively. The tube is exhausted to a pressure varying between 0 and 10 mm. of mercury and the gases admitted. An electric discharge is then passed through and the foreign gases are absorbed, leaving the neon in a substantially pure state. The minimum surface area is 1.5 sq. dcm. per ampere. A comparatively large surface area is desirable since the neon is absorbed so much more slowly than the other gases.

The process is particularly applicable when the puri-

fied neon is to be used in a rarified state in the enclosure in which it has been obtained. The neon is extremely permeable to electric discharge and has found application in detectors of Hertzian waves, luminous tubes, etc. The process is of especial interest as it makes it possible to separate neon from helium effectively. (1,191,495, July 18, 1916.)

Alloys

Heat-Resisting Alloy.—A patent has been granted to JOHN C. HENDERSON of Washington, D. C., and assigned by him to the Driver-Harris Wire Company of Harrison, N. J., on the manufacture of cast articles of nichrome. A description of experimental work done on these articles was given in this journal, Vol. XV, page 159, Aug. 1, 1916. The articles are intended to withstand temperatures of from 1000 deg. Fahr. upwards without suffering corrosion, pitting or oxidation. The composition is nickel 60 per cent, iron 26 per cent, chromium 12 per cent, and manganese 1½ per cent. If substantially carbon free (less than 0.4) the alloy can be machined, rolled or forged. The alloy requires a high melting heat, but when once sufficiently melted can be cast in the ordinary manner. Some of the articles mentioned are molds for die casting, valves and valve seats for internal combustion engines, crucibles, outer casings for crucibles, linings for molds and crucibles, annealing boxes, case-hardening or carburizing boxes, and other apparatus. The manganese is not essential but is merely the remnant of manganese from the raw materials used.

When subjected to oxidizing temperatures, a slight film of oxide forms on the surface of the article, which is strong and durable, and resistant to sulphuric and hydrochloric acids and alkalies. This oxide is non-flaking and adheres strongly to the mass. (1,190,652, July 11, 1916.)

Measuring Water with a Weir Meter*

BY E. G. BAILEY

A V-notch or rectangular weir offers many advantages for measuring water at or near atmospheric pressure. The flow curve is such that greater accuracy is readily obtained over a wider range in rate of flow than with the Venturi or Pitot tubes. From an accurate knowledge of the flow curve for any given shape of weir notch, it is possible to use the level of the water above the notch to continuously record the rate of flow and integrate it so that the total may be read from time to time. The nature of the flow curve of a V-notch weir as shown in Fig. 1 brings out clearly the point that at low rates of flow there is proportionately a great deal of head, or power, to operate any float-driven mechanism. The converse is true at the higher heads where a very slight change in head means a much greater change in rate of flow.

The accuracy of the V-notch has never been questioned but the points of primary importance are to accurately measure the head and to be sure that this measurement is referred back to the true zero of the notch. These points are difficult enough when using hook gages with micrometer screws in a hydraulic engineering laboratory, and even more so when continuous recording and integrating mechanism is used to measure the rate and total flow.

The zero level can be readily obtained in test or calibration work if a permanent hook gage point is rivetted to the weir plate as shown in Fig. 2. This can be accurately located in the machine shop and is absolutely correct by construction.

*A paper read before the June meeting of the Ohio Society of Mechanical, Electrical and Steam Engineers at Cleveland. Slightly abstracted. The author is president of the Bailey Meter Company of Boston, Mass.

It is always preferable to have chart records on uniformly graduated charts and in order to use the best form of integrating devices it is essential to have a motion directly proportional to the rate of flow instead of proportional to the head.

There are many ways in which this may be accomplished with more or less accuracy, but the motor with the simplest mechanical construction always gives the best satisfaction and continued accuracy over a long period of time.

The mechanism used in this apparatus operates on the buoyancy principle, as shown in Fig. 2. The displacing members are exactly balanced and weighted so that they are heavier than water and do not act as floats. If they were of equal and uniform cross sectional area the rising of the water level would produce no motion but would merely cause them to become lighter on their knife edge supports by an amount equal to the weight of water displaced. But by properly shaping these spun copper displacing members a powerful motion that is directly proportional to the actual flow is obtained directly from the main shaft itself.

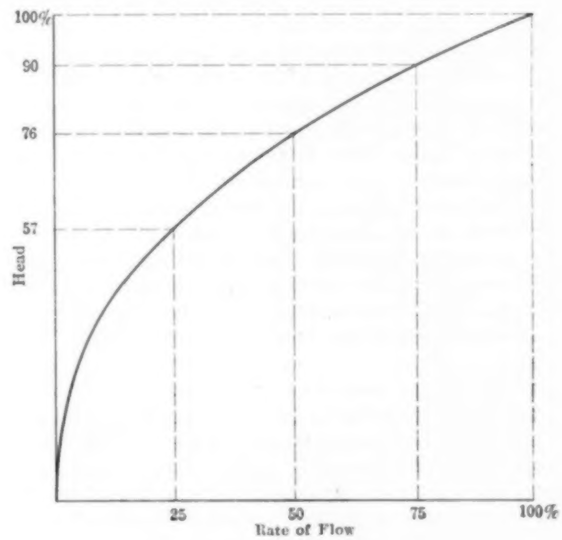


FIG. 1—FLOW CURVE

Thus when the rate of flow is 25 per cent of the maximum capacity of the meter, the motion given to the pen is 25 per cent of the total motion. At this point the level of the water has increased to 57 per cent of the total range in head.

The motion of the displacing members, and also the recorder pen, has not been relatively as much as the change in head, but it is directly proportional to the rate of flow. The total motion of each displacing member is, of course, less than the total change in water level. The maximum head is 10 in. and the corresponding motion of the displacing member is 4 in.

The characteristic of the flow curve of a V-notch weir is the basis for the often repeated argument of its great accuracy at the low rates of flow. But upon closer analysis it is found that this argument is a boomerang when considered in relation to the higher rates of flow, unless the recording mechanism is properly designed. An error of a few hundredths of an inch in a hook gage or straight float that rises directly with the water level may mean as much as 5 per cent error in the flow of reading at the higher rates.

The design of this weir meter entirely obviates the

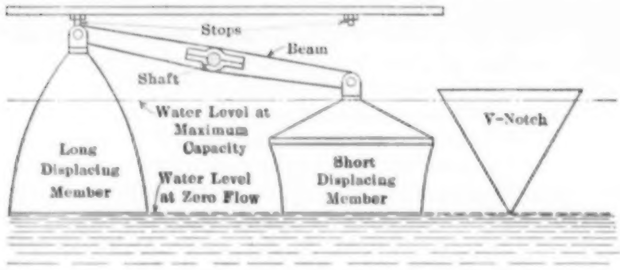


FIG. 2—PRINCIPLE OF METER

possibility of such an error, for the relative position of the two displacing members is made right by construction, and no changes can possibly take place to alter it. The pen and integrator can be set to their true zero so long as the water level is within ½ in. of the bottom of the notch, and there will be no error at the higher readings.

The working arrangement of these displacing members is shown in Fig. 3. The beam which carries the displacing members on monel metal knife edges is fastened to a shaft supported on monel metal knife edges. The end of this shaft extends through a pressure-tight bearing and carries the recorder pen and integrator driving directly on its outer end.

The question of integrating the flow of any fluid brings up many problems that have been more or less troublesome on other types of meters as well as of the weir type. Principal among these are imperfect drive due to vibration and the wearing smooth of the driving disc.

A detail of the integrator which has been found very satisfactory is as follows: In this the disc is driven by the same clock movement which drives a chart; the disc making two revolutions per hour. The counter is suspended from a knife edge bearing on the clock frame and is moved across the disc by an arm extending from the main shaft which also carries the recorder pen. The follower wheel which is in contact with the clock-driven disc bears in the center for zero flow and is moved outward to a radius of 3½ in. at maximum rate of flow. This follower wheel is provided with a large number of rollers on its circumference which practically eliminate friction as it is moved across the disc and also prevents wearing the disc smooth, so that continued accuracy is obtained over an indefinite period of time without attention. The axis of the follower wheel is mounted slightly inclined from the perpendicular to the clock-driven disc so that the follower wheel bears against its projecting edge instead of its extreme circumference. This gives a greater arc of contact and eliminates error due to slip. This wheel is held against the disc by a flat spring and a small pressure of this part prevents any error due to vibration. This arrangement also simplifies the construction so that spur gears are used to drive the countertrain.

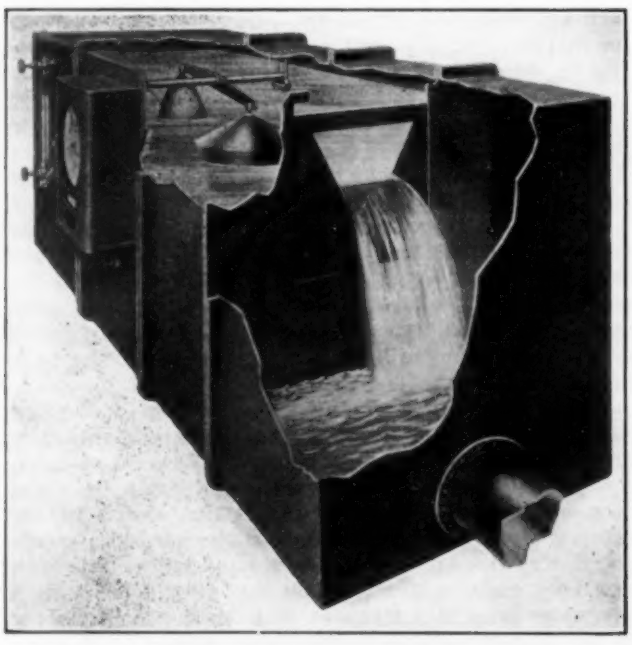


FIG. 3—WORKING ARRANGEMENT OF METER

A record of one of these meters when receiving returns from one system which had an electric motor-driven pump that is intermittent in its action due to a float control showed interesting results. The meter calibration test Jan. 28th was made on this meter on this day when the rate of flow was varying from less than 2 per cent to over 90 per cent of the meter's rated capacity, every 8 to 10 minutes. The last calibration test which was made was at a very low rate, it being only 1240 lb. per hour, which is 2½ per cent of the meter capacity. One of these meters agreed within 2.7 per cent of actual weight on the 15-hour tests, and while the other meter shows a larger percentage error yet this is equivalent to only 1 per cent at 35 per cent capacity, and this error would be produced if the follower wheel was only one hundredth of an inch out of its true adjustment, which was found to be the case at the end of this calibration.

A record of the water temperature is also made on the same chart with the rate of flow. This is accomplished by means of a recording thermometer having its bulb located in the flowing water. If temperature record is not desired the full pen motion on a 12-in. chart may be had.

New Design of Automatically Controlled Low-Pressure Valve

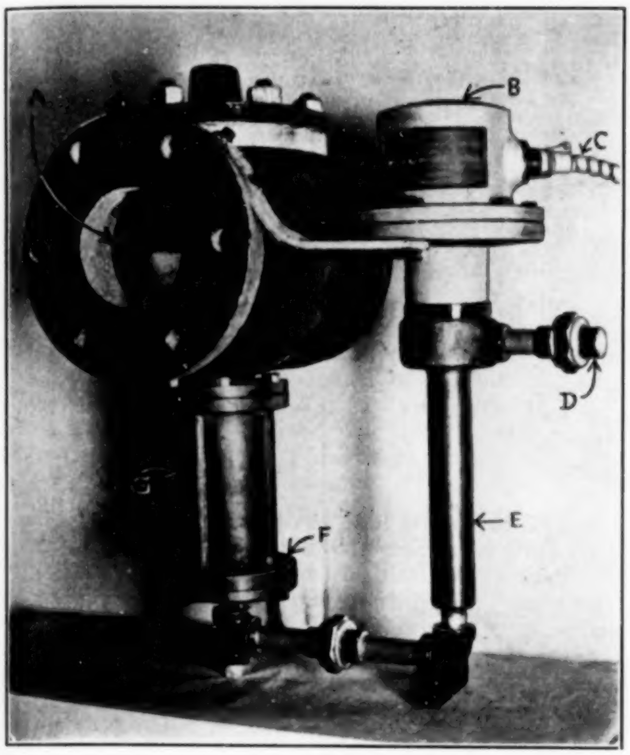
The adjoining illustration shows a low-pressure steam valve, electrically operated, requiring 0.5 amp. and 110 volt direct current, which has been developed by the Geissinger Regulator Co., 203 Greenwich Street, New York City. It is used in connection with the automatic "equitherm" controller of temperatures, and has proved to be an economizer of waste steam in large plants. It is used on apparatus requiring low-pressure steam.

The valve opens and shuts under the guidance of an electric thermostat, the lead *C* shown in the illustration connecting the thermostat with the magnet head *B*. The fall of temperature past the critical degree closes the thermostatic circuit, energizes the relay coil in the control cabinet, and closes the valve coil circuit contained in the magnet head *B*.

This attracts the armature of the pilot valve stem in the pilot valve *E*, which on lifting allows high-pressure steam from line *D* to pass through the pilot valve and under the piston contained within the high-pressure cylinder *G*.

A rod connects the piston and the bottom of the low-pressure valve disk, so that when the piston rises the low-pressure valve disk is lifted off its seat, against the low-pressure steam, which is on top of the valve disk. The low-pressure inlet on top of the valve disk is shown at *A*.

The valve works on the principle of a check valve. It takes pressure and gravity to close it. The high-pressure steam is used as an agent to open the low-pressure valve automatically. There is no waste of the high pressure, as it acts as a heating unit with the



AUTOMATIC LOW PRESSURE VALVE

low-pressure steam. This type of low-pressure valve makes it possible to utilize exhaust steam. When the supply of low-pressure steam is not enough at a certain time the high-pressure will take care of the difference when necessary. Under ordinary conditions control can be maintained within 1 to 2 deg. Fahr.

Enlarging Photographs Without the Use of a Lens

An interesting American Physical Society paper by **Alfred J. Lotka** of the General Chemical Company of New York City, is published in the June, 1915, issue of *Physical Review*, describing a new method for enlarging photographs without the use of a lens. This method was developed by the author as the result of an observation of a peculiar distortion presented by the appearance of certain moving objects.

The method consists in moving the negative to be

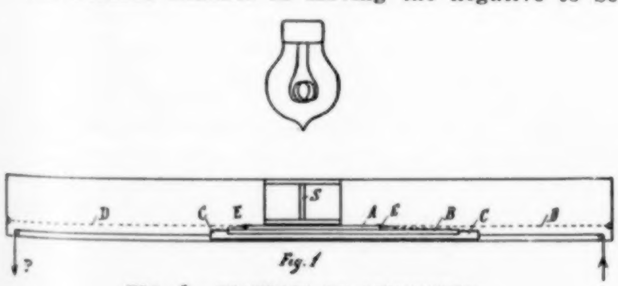


FIG. 1—DIAGRAM OF APPARATUS

enlarged past a narrow slit source of light, and at the same time moving a sensitive plate under the negative at a speed equal to some constant multiple n of the speed of the negative.

On development of the sensitive plate a positive transparency is obtained, in which all lines of the original negative which were parallel to the slit during the exposure are unaltered, while all lines at right angles to the slit are magnified in the ratio $n : 1$.

This positive is subsequently subjected to a repetition of the process practised on the original negative, but with the motion now at right angles to the lines drawn out n-fold in the first operation. The result of the second operation is a negative geometrically similar to the original, but with the linear dimensions enlarged n times, or the area n^2, as will be easily understood.

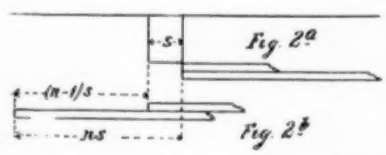


FIG. 2—DIAGRAM OF APPARATUS

The apparatus employed for carrying out the process has been constructed on exceedingly simple lines, with the use of material readily obtainable on the market. The slit is made with two strips of brass picked from the stock of a wholesale hardware store and having received no other treatment than a cleansing with a brass polish.

The ratio n of the velocities in the apparatus so constructed is 2, and is secured by the simple expedient shown diagrammatically in Fig. 1. In this drawing the original negative is represented at A, the sensitive plate at B, and the slit at S. The carrier C, on which the plate B rests, has attached to it at each end a silk thread D, which passes through an eye E, attached (with gummed paper) to the glass plate of the negative (when a celluloid film is used, such film may be attached with gummed tape to a glass plate). The further end of the silk cord D is attached to the end block of the box containing the negative and plate during exposure. The carrier C slides on the bottom of the box, between guides adjusted to fit the sides of the plate.

It will readily be seen that, in accordance with the principle of the single movable pulley, the velocity of the sensitive plate is always double that of the negative.

Any means, such as a hand-pull at P, may be employed to impart uniform motion to the negative. A cylinder containing water through which a fairly snug-fitting perforated piston is drawn makes a good dash-pot to regulate the motion. This and a still simpler and exceedingly compact device for this purpose is a subject of a pending patent application.

The adjustment of the lamp vertically above and in the plane of the slit is effected by looking down at the lamp and its reflection in the glass covering the slit. When the filament, its image and the line of the slit coincide in the line of sight, the filament is in the plane of the slit. It was found that with a slit 6½ in. long good results were obtained with a filament of six or seven coils placed about 1 ft. from the slit.

Among the advantages which the new method presents is uniformity of illumination over the entire field; geometric similarity to the original of the image produced, *i.e.* absence of distortion such as spherical aberration introduces; compactness and simplicity of apparatus, replacement of lens by a simple slit and hence low cost of the apparatus.

The process necessitates two successive exposures, but this is true also of the ordinary method when a negative is to be prepared from a negative.

The example shown in the accompanying half-tone illustration gives an idea of the working of the process, though it does not represent the best that can be done in the way of definition.

The limiting separation which the apparatus will effect can be figured as follows:

Consider a point right on the edge of the negative. This will begin to be reproduced on the sensitive plate as soon as the negative and plate are in the position

shown in Fig. 2a. (The slit is here shown on a greatly enlarged scale.) The same point will continue to be reproduced until negative and sensitive plate are in the position shown in Fig. 2b. It will therefore be drawn out into a line of length $ns - s = (n-1)s$.

FIG. 3 — HALF-TONE COPY OF ORIGINAL PHOTOGRAPH

FIG. 4—COPY OF DISTORTED POSITIVE TRANSPARENCY OBTAINED IN FIRST STEP OF PROCESS

FIG. 5—COPY OF ENLARGEMENT OBTAINED IN SECOND STEP

Now consider two points, a distance d apart in the negative. In the copy they will appear as two lines $(n-1)s$ long and with their centers nd apart. These two lines will just coincide at their ends when

$$nd = (n-1)s,$$

$$d = \frac{n-1}{n}s.$$

This distance

$$d = \frac{n-1}{n}s.$$

between two points on the original negative represents the dimit of separation: Two points a distance greater than d apart will be separated, two points nearer together than d will not be separated.

For $n = 2$ as in the apparatus constructed, we have

$$d = \tfrac{1}{2}s.$$

Thus, for example, a comparatively coarse slit 1/100 in. wide, will still separate points just a little over 1/200 in. apart.

The process and apparatus here described are protected by U. S. Pat. 1,176,384 of March 21, 1916, issued to Alfred J. Lotka.

Personal

Mr. **Walter A. Barrows, Jr.,** of Brainerd, Minn., who for some years has been engaged in iron mining in Minnesota, has been elected president and general manager of the Thomas Iron Co. of Easton, Pa. He succeeds **Ralph H. Sweetser,** who recently resigned.

Mr. **Samuel H. Dolbear,** consulting mining engineer, of San Francisco, was in New York a few days during the middle of August. He went from New York to Washington and from there back to San Francisco.

Mr. **R. H. Fash,** chief chemist of the Chickasha Cotton Oil Co., has been appointed active vice-president of the Fort Worth Laboratories, Fort Worth, Tex.

Mr. **E. T. Foote,** formerly of the New York office of the Cutler-Hammer Mfg. Co., and at one time in the engineering department at its Milwaukee factory, has recently been put in charge of the Boston office, located in the Columbian Life Building. Mr. Foote's experience in the engineering department and sales engineering work in New York fit him admirably for his new position.

Dr. **Milton Hersey** of Milton Hersey Co., Ltd., Montreal, Canada, has returned from a trip through the Northwest, where he has been investigating the resources and industrial possibilities of the country for the Canadian Northern and Grand Trunk Pacific Railways. His company has recently opened an office in New York City at 198 Broadway.

Mr. **M. H. Kuryla** is in charge of erection of the new electrolytic zinc plant of the Judge Mining & Smelting Co., Park City, Utah. In our issue of Aug. 1 it was erroneously stated that Mr. M. H. Atwater was in charge.

Mr. **S. G. Lilja,** formerly with the Helsenborg Copper Works, Helsenborg, Sweden, is now engineer with Hamilton & Hansell, Stockholm. He has recently been in this country looking over the electric furnace field.

Mr. **N. Petinot,** formerly with the Titanium Alloy Mfg. Co. of Niagara Falls, N. Y., has opened an office at 200 Fifth Avenue, New York, as electrometallurgical engineer specializing in ferroalloys.

Mr. **Wm. Printz,** formerly assistant sales manager of the Brown Instrument Co., Philadelphia, Pa., will be in charge of the new Detroit office of the company opened on Sept. 1. The office will be located at 612 and 613 Chamber of Commerce Building.

Prof. **M. C. Whitaker,** professor of chemical engineering at Columbia University, has been granted leave of absence for the first term of the academic year 1916-1917.

Industrial Notes

The Thwing Instrument Co., Philadelphia Pa., has issued general catalog No. 8, describing Thwing electrical recording pyrometers. Three types of pyrometers are described, viz.: thermoelectric, radiation, and resistance.

The Foxboro Co., Foxboro, Mass., has issued Bulletin No. 104, describing Foxboro indicating and recording thermometers. Four classes of instruments are described, ranging in temperature scales from 60 deg. F. to 900 deg. F.

The **Elyria Enameled Products Company,** Elyria, Ohio, has erected a new chemical laboratory equipped to carry on a full line of analytical and research work. The company feels that the addition of facilities afforded will enable it to be of larger service to its friends.

Petroleum Output in 1915.—The petroleum output in the United States in 1915 broke all previous records with a production of 281,104,104 barrels. This is nearly a 6 per cent increase over 1914. The average price received at the well was 64 cents per barrel. Oklahoma led in production, with nearly 98,000,000 barrels. California was second with about 86,600,000 barrels. The next largest producer was Texas, with about 25,000,000 barrels.

New Chemical Plant in St. Louis.—The Mineral Refining & Chemical Co., a company formed last January, is constructing a large plant at St. Louis, Mo., for the manufacture of a substitute for white lead and zinc white in paint manufacture. The daily capacity will be 50 tons. Eight wood and stone buildings will comprise the plant. The construction work is being done by the Fruin-Colnon Contracting Co. Jose Harimon, president of the Spanish Bank of Commerce and the Spanish Bank of Cuba, at Havana, is president of the new company.

Pyrometers.—The Brown Instrument Company, Philadelphia, Pa., are now manufacturing indicating and recording pyrometers for ranges from 400 deg. F. to 3000 deg. F. (1600 deg. C.), and also recording thermometers for low temperatures. These will be on exhibit at the coming Exposition of Chemical Industries in New York in September.

C. O. Bartlett & Snow Co., Cleveland, Ohio, has received the contract for equipping the plant of the Cosmopolitan By-Products Co., New York City, with the Cobwell system of garbage reduction.

New Refiner for Paper and Pulp Industry.—The Manitowoc Engineering Works, Manitowoc, Wis., has issued a circular describing the Howard refiner, which has found successful application in paper, pulp, and other industries.

The Cutler-Hammer Mfg. Co., Milwaukee, Wis., has leased new and larger New York City offices on the nineteenth floor of the Hudson Terminal, 50 Church Street, providing nearly double the space previously occupied. Mr. W. C. Stevens is manager of this office.

Aparatos Destiladores de Agua.—Messrs. Eimer and Amend, New York City, have issued a pamphlet in Spanish describing the Barnstead & Stokes water-distilling apparatus.

Cost System for Manufacturers.—The Federal Trade Commission, Washington, D. C., has issued a pamphlet entitled "Fundamentals of a Cost System for Manufacturers." This pamphlet shows briefly the importance of accurate manufacturing costs and the fundamental principles underlying them, and should prove of value to a great many manufacturers who have not gone into detail in the subject of costs.

The Denver Fire Clay Company, Denver, Colo., has issued an attractive booklet, designated Catalog D, describing Case metallurgical furnaces for melting, refining, assaying, tempering, annealing and enameling. Furnaces are described operating on fuel oil, gasoline, gas, coal, coke and wood.

Multiblade Fans.—The Clarage Fan Company, Kalamazoo, Mich., has issued catalog No. 5, describing the Clarage-Kalamazoo multiblade fan for heating or ventilating installations. The catalog includes capacity and dimension tables for facility in determining what size to use.

Trust Laws and Unfair Competition.—The U. S. Commissioner of Corporations, Joseph E. Davies, has just issued a long report on "Trust Laws and Unfair Competition." This report grew out of the preparation of a large amount of material in connection with the antitrust legislation enacted recently, and it was decided by the Secretary of Commerce and the Commissioner of Corporations that the material was of such a character that it ought to be placed in permanent form to be available for publicists, economists, business men and statesmen for reference. This treatise designs to cover in compact form the laws of the various countries of the world pertaining to the prevention or regulation of monopoly by government, and the prevention of unfair practices of competition. The last chapter is on the activities of trade associations and their relation to laws concerning competition in the United States.

Determination of Aluminium.—The Bureau of Standards has published the results of research work done on the determination of aluminum, as Scientific Paper No. 286. From observations made with a hydrogen electrode and with suitable indicators, the conditions for the quantitative precipitation of aluminium hydroxide by ammonium hydroxide were determined. In practice, the completion of precipitation may be defined by means of methyl red or rosolic acid. The effect of various factors upon the precipitation, washing and ignition of the precipitate was determined. The procedure for obtaining accurate results is also described.

Vanadium Company Sold.—The American Vanadium Company of Pittsburgh, a $700,000 corporation, formed in 1906 to mine and sell vanadium, has been purchased by a group of Eastern capitalists, and a new company formed to take over and operate the old company. The new company will have a capitalization of $13,500,000, and will operate under the old name. James J. Flannery of Pittsburgh, president of the old company, will become chairman of the board, and J. J. Replogle, now vice-president and general manager of sales, will be president. The American Vanadium Company controls the largest part of the known vanadium deposits of the world, its use in high-speed steel having given rise to a considerable production.

Digest of Electrochemical U. S. Patents

PRIOR TO 1903

Arranged according to subject-matter and in chronological order.

Compiled by Byrnes, Townsend & Brickenstein, Patent Lawyers, National Union Building, Washington, D. C.

Aqueous Bath, Cathodes Metallizing

211,610, Jan. 21, 1879, Napoleon W. Williames of Philadelphia, Pa., assignor to himself and Wm. W. Keys, of same place.

Relates to bronzing iron railings, etc., for ornamental iron work, enclosures, etc. The iron is first coated with a paraffin varnish, and this coated with plumbago; it is then immersed in a copper-plating solution, such as the sulfate or chlorid, and copper deposited thereon.

215,034, May 6, 1879, Isaac Adams, Jr., of Boston, Mass.

Relates to covering metals with vulcanized rubber. The metal article, if other than copper, is first coated with a thin film of copper; if the metal article is copper, then a thin film of other metal is first applied, such as tin, nickel, iron, etc., and upon this is applied a thin film of copper. Instead of a film of copper, one of silver may be used. Copper and silver have a tendency to unite with the sulfur in the vulcanized rubber, and it is this property which makes these metals useful for this purpose. After the copper film is formed, the rubber is applied and vulcanized to the copper in a mold, or under pressure.

226,873, April 27, 1880, Irwin M. O'Donel of Pittsburgh, Pa., assignor of one-half of his right to William J. Fullerton of same place.

Relates to the formation of molds having non-oxidizable surfaces, for the manufacture of molded glass, etc. A pattern of the article to be molded is made of clay, wax, or other suitable substance, and a coating of

graphite applied to the surface to be imitated. The pattern is then immersed in a solution of platinum, cobalt, or other non-oxidizable metal or alloy, and a deposit thereof produced on the graphite. The mold is then removed to another vat containing a solution of a cheaper metal, and a deposit of sufficient thickness applied to strengthen it. The deposited shell is then removed and placed in a suitable mold, and a sufficient amount of iron is then cast to or upon it to strengthen and preserve it. It is then finished on its edges, etc., and is ready for use. Metal molds which need to be repaired may be electroplated with a non-oxidizable metal to reduec them to the desired size. The alloy preferred is composed either of iridium or platinum and copper, in the proportion of about one-half each.

227,370, May 11, 1880, Albon Man of Brooklyn, N. Y.

Relates to uniting or framing pieces of glass, china, porcelain, crockery, stoneware, etc. The materials may be first fire-gilded, silvered, or platinized on the parts to be metalized; or the materials may have a coating of lead, zinc, or other metal, or oxids of metals or their salts, applied in a hot state, to the surfaces to be coated, to render it conductive. Or an amalgam of mercury and tin or other metal may be applied; or the surfaces silvered by the precipitation of metallic silver by the mirror silvering process. The coated pieces are then assembled and electroplated, thereby uniting or joining into a unitary structure. Or the several separate pieces may be copper-plated, and then soldered together. The method is said to be useful in securing several glass or porcelain pieces together, or to metal, such as the parts of philosophical apparatus, incandescent lamps, ornaments, etc.

240,615, April 26, 1881, Frederick S. Shirley of New Bedford, Mass.

Relates to the manufacture of molds for making pressed glass, etc. A suitable model of the article to be made with the desired ornamentation is coated with graphite and electroplated with a heavy deposit of copper or other suitable metal or alloy. The deposit is then cut in suitable sections to make a sectional mold, studs or lugs being first secured to the backs of the deposited metal to serve as anchors in reinforcing metal later cast against the backs of the mold sections.

299,055, May 20, 1884, Thomas W. Collins of New York, N. Y., assignor of one-half to Alfred H. Smith & Co., of same place.

Relates to securing diamonds in the edges of cutting tools, by depositing copper in the recess in the tool in which the diamond is placed. The diamond is first coated with copper as follows: It is dipped in a solution of phosphorus in bisulfid of carbon, then dried in the atmosphere. It is then dipped in silver nitrate solution until it becomes black. It is then washed, and if further metallic coat is desired, it may be dipped in chlorid of gold solution. It is then copper-plated. Instead of the above, after receiving the phosphorus coating, the diamond is placed in a solution of nitrate of mercury, and thereafter copper-plated. The copper-plated diamond is then placed in its dovetail shaped recess, and copper deposited in the space around the diamond to secure it in place. Other abrasives, such as corundum, emery, etc., may be secured in this manner.

321,711, July 7, 1885, William A. Gay of Newark, N. J.

Relates to the deposition of metal upon the surface of earthenware and the like, and consists in mixing finely-powdered clay, coke, etc., with sugar solution, tar, or other carbonaceous material, in the approximate proportions of 14 lb. of syrup or tar to about 45 to 50 lb. of the base or powder. The unsized baked earthenware is covered at the desired places with the above mixture, and the whole submitted to pressure under moderate heat until the mass has firmly adhered to the article. The coated articles are then placed in crucibles, the spaces being filled with sand to exclude air, and the crucibles covered. They are then heated to a dull red heat for from one to two hours, and then allowed to cool. The carbonized surfaces are then cleaned free from sand, and are ready to receive the metallic deposit.

339,431, April 6, 1886, William J. Ladd of New York, N. Y.

Relates to an apparatus for connecting electrotype molds to conductors, and consists of a metallic hanger having mold-suspending hooks which are insulated. Contact with the metallic hanger and mold is made by an independently removable metallic contact piece capable of being secured to the hanger and which presses tightly against the conducting surface of the mold. The circuit may be broken at any time by removing the contact piece, without removing the mold from the electrolyte. The contact piece may be provided with a clock dial and adjustable hands to indicate the time the circuit should be broken, etc.

344,397, June 29, 1886, Robert F. Nenninger of Newark, N. J.

Relates to the manufacture of an electroplated fabric consisting of flexible material such as paper-pulp formed into sheets and dried. The fabric is then made waterproof by soaking in linseed oil, etc., and drying. The waterproof fabric is then stitched through at many points on both sides over each entire surface with bare copper wire, the wire extending for short lengths at each stitch on each surface of the fabric. One or both surfaces of the fabric are then coated with graphite, and the fabric immersed in the electrolyte. The metallic deposit anchors itself to the copper wires and spreads over the entire fabric. When completed, the plated fabric may be used for floor or wall covering, lining refrigerators, etc.

347,195, Aug. 10, 1886, David S. Plumb of Newark, N. J.

Relates to ornamenting glassware and the like, such as pitchers, etc., and consists in applying to the surface of the glass a continuous network or openwork of wax, glass cement, paint, etc., and producing the design in the wax, etc. A coating of bronze powder or graphite is now applied to the ornamented wax, and then electroplated with gold, silver, etc. The electroplate may be engraved if desired.

360,672, April 5, 1887, Otto S. Fertig of New York, N. Y.

Relates to hangers for suspending electrotype molds in an electrolyte, and refers to an earlier patent, number 151,892. The hanger is provided with two insulated metallic hooks by which the mold case is suspended, to prevent it from tilting sideways, and a metallic strip to make electric contact with the face of the mold.

362,927, May 17, 1887, Edward A. Blake of Chicago, Ill.

Relates to an apparatus for coating electrotype matrices with graphite. The matrix is placed upon a support in a suitable box having an outlet at the bottom, and through the top of which is directed a blast of air carrying graphite; the graphite is blown directly upon the matrix, into all the depressions, and provides an even and smooth coat of graphite over its entire surface. The excess of graphite is blown away and collects in the lower part of the box, from which it passes through the outlet therein and through a conduit up to a hopper which communicates with a blower supplying the blast of air to the matrix.